# Malheur Lakes Redband Trout Conservation Plan

**Public Draft**

**April 13, 2018**

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# EXECUTIVE SUMMARY

The Oregon Department of Fish and Wildlife (ODFW) has developed a conservation plan for redband trout (*Oncorhynchus mykiss spp*) that is consistent with guidance provided in Oregon's Native Fish Conservation Policy. The Malheur Lakes Redband Trout Conservation Plan provides information and management guidance for redband trout within the Malheur Lakes basin. The current health of nine existing redband trout populations in this SMU is described, and management strategies are proposed that are intended to maintain and improve their status by addressing those factors that are most limiting to the fish.

The Malheur Lakes SMU resides in the Oregon portion of the Great Basin in southeast Oregon. Redband trout in the Malheur Lakes SMU reside in the streams that flow off of the Steens Mountains towards Burns in the SMU's southern end, and in streams flowing off of the south end of the Blue Mountains to the north and west of Burns in the SMU's northern end.

The streams in this SMU flow into a closed basin (no outlet to larger rivers and the ocean) and often do not connect with other nearby streams. As a result, there is little exchange of genetic traits between populations, which has led to each population being genetically unique. This region of southeast Oregon is characterized by an arid climate, with periods of wet and dry years, that has led to the evolution of a trout that is able to persist through the dry years, and yet be resilient enough to rebound and flourish during the wet years.

The ODFW assessed the health (status) of each of the nine populations as a whole (Chapter 2) utilizing all available information. The assessment found that the Malheur Lakes SMU currently passes the criteria for being viable and capable of persisting into the future. The assessment also found that some redband trout populations were at greater risk of not persisting into the future than others. Some of this risk is a consequence of the geologic/geographic configuration of the basins in which the fish evolved, and some of the risk is due to a loss of access to habitat and a deterioration of its quality.

ODFW proposes a preferred status (desired status) for the redband trout populations within the Malheur Lakes SMU that improves the habitat and distribution of all populations (Chapter 3). These will be improved through the implementation of actions that address those limiting factors. In addition, this plan provides a description of the conditions (Chapter 3) that would indicate individual populations, or the entire SMU, are at imminent risk of becoming at risk of extinction (critical status), and warrant consideration for protective measures.

This Conservation Plan provides information that describes those human-caused factors that are most limiting the redband trout in each population (Chapter 4). The most common limiting factors identified by a team of local experts were related to a loss of water quantity, water quality, and habitat quality.

Many of the populations were difficult to assess status or limiting factors because a significant proportion of the streams had not been surveyed in a very long time. As a consequence, this plan took the conservative approach of assigning a higher risk rating to those populations for which very little is known of their status or condition.

The strategies identified in this Conservation Plan to address the limiting factors (Chapter 5) all rely on voluntary efforts to improve conditions for redband trout. As a result, the goal of ODFW will be to work with landowners and partners, such as watershed councils, soil and water conservation districts and the Natural Resources Conservation Service, to design, fund and implement actions intended to help improve the health of targeted redband trout populations.

The Malheur Lakes Redband Trout Conservation Plan outlines the need to gather more information on redband trout in order to better understand their status, and to ensure that the actions taken to improve their status are effective (Chapter 6). A need to develop new approaches to monitoring the fish and their progress is identified as necessary, due to the labor-intensive nature of past monitoring.

Finally, this Conservation plan outlines a process to periodically check in on the implementation of this plan and how the fish are doing (Chapter 7) to better ensure that progress is being made towards the desired status – the long-term sustainability of the redband trout populations.

# CHAPTER 1

# INTRODUCTION AND BACKGROUND

## 1.1 Purpose

The purpose of this conservation plan is to outline a strategy to ensure the long-term viability of interior redband trout (*Oncorhynchus mykiss spp*)[1] populations in the Malheur Lakes basin. The goal is to achieve a level of desired biological status that provides ecological and societal benefits as defined by the Oregon Department of Fish and Wildlife's (ODFW's) Native Fish Conservation Policy (NFCP, ODFW 2002).

The NFCP was adopted by the Oregon Fish and Wildlife Commission (OFWC) in 2002 and is designed to conserve and recover native fish in Oregon. The intent of the NFCP is to provide guidance for managing the impacts of hatcheries, fisheries, habitat, predators, competitors, and pathogens to achieve sustainable production of naturally produced native fish. The policy has three areas of strategic emphasis. The first is defensive to manage threats in a manner that avoids serious depletion of native fish. The second is more proactive to restore and maintain native fish at levels providing ecological and societal benefits. The third ensures that, consistent with native fish conservation, opportunities for fisheries and other societal resource uses are not unnecessarily constrained. This approach will allow Oregon to play a vital role in the recovery of ESA listed species and the prevention of future listings.

The policy is implemented through this conservation plan that identifies the area and populations to be managed (Chapter 1), the existing (Chapter 2) and desired status (Chapter 3) of native fish in those populations, key factors limiting the populations from achieving the desired status (Chapter 4), management options to address these factors (Chapter 5) and monitoring required to evaluate the success in reaching the desired status (Chapter 6). Native fish conservation plans such as this plan are developed in collaboration with management partners and the public.

## 1.2 Development of this Conservation Plan

This conservation plan was developed by ODFW's Conservation and Recovery Program with the assistance of local ODFW biologists, the Native Fish Investigations Project and local experts from co-management agencies. Two groups were formed to help in the development of this plan: the Conservation Planning Team and the Technical Team.

### 1.2.1 Conservation Planning Team

A group of ODFW scientists from the Conservation and Recovery Program (C&R), the Native Fish Investigations Project (NFI) and the Malheur Watershed District (WD) formed the Conservation Planning Team (Planning Team – see Table 1-1). The Planning Team was responsible for

[1] "Redband" trout in this plan refers to rainbow trout (*Oncorhynchus mykiss spp*) that originate from areas in Oregon east of the Cascade Range. These trout are often characterized by a more noticeable red band along their sides than rainbow trout found west of the Cascade Range.

gathering all of the available information on redband trout in the Malheur Lakes area, analyzing the data to help develop and apply viability criteria, developing the outline for the plan, and defining the Species Management Unit (SMU).

**Table 1-1. Members of the Conservation Planning Team and their ODFW affiliation in parentheses** *(MWD = Malheur Watershed District, NFI = Native Fish Investigations Project (Fish Division), C&R = Conservation and Recovery Program (Fish Division))***.**

| | |
|---|---|
| Dave Banks – Author (MWD) | Steve Jacobs – (NFI-retired) |
| Shaun Clements – (NFI) | Dave Jepsen – (C&R) |
| Chip Dale – (MWD-retired) | Mike Meeuwig – Author (NFI) |
| Kevin Goodson – Author (C&R) | Ray Perkins – (MWD-retired) |
| Stephanie Gunckel – Lead author (C&R) | Ben Ramirez – (MWD) |
| Bob Hooton – (MWD-retired) | Tom Stahl – (C&R) |
| Shannon Hurn – Author (MWD) | Tim Walters – (MWD) |

### 1.2.2 Technical Team

The technical team was comprised of ODFW and co-managing scientists familiar with redband trout and their habitats in the Malheur Lakes area (Table 1-2). The Technical Team was responsible for reviewing and approving the viability criteria and identifying the limiting factors for all redband trout populations in the Malheur Lakes area.

**Table 1-2. Members of the Technical Team and their affiliations.**

| | |
|---|---|
| Chad Abel – Burns Paiute Tribe | Bob Hooton – ODFW (retired) |
| David Banks – ODFW | Shannon Hurn – ODFW |
| Christine Bates – BLM | Jason Kesling – Burns Paiute Tribe |
| Linda Beck – USFWS, Malheur Refuge | Erica Maltz – Burns Paiute Tribe |
| Tim Bodeen – USFWS, Malheur Refuge | Ray Perkins – ODFW (retired) |
| Kyle Bratcher – ODFW | Roger Smith – ODFW (retired) |
| Jim Dastyck – USFWS, Malheur Refuge | Rick Vetter – USFS (retired) |
| Lindsay Davies – BLM | Mitch Willis – SWCD (retired) |
| Stephanie Gunckel – ODFW | |

## 1.3 State and Federal Status

State and Federal management agencies identify redband trout populations in Malheur Lakes Basin as sensitive or vulnerable to extinction risk and worthy of conservation actions and warrants this conservation plan as necessary.

### 1.3.1 State Status

The Native Fish Status Report (NFSR, ODFW 2005) indicated that the aggregations of redband trout populations in Malheur Lakes are compromised and in need of conservation and restoration measures. Based on the assessment in the NFSR the Malheur Lakes redband trout is one of 51 fish species/population aggregates included on the state sensitive species list (ODFW 2008). This list identifies species, subspecies or populations that are facing one or more threats to their population and/or habitat. Malheur Lakes Basin redband trout populations are listed as sensitive, facing one or more threats to their populations and/or habitat. Implementation of appropriate conservation measures to address these threats may prevent them from declining to the point of qualifying for threatened or endangered species status.

The NFSR (ODFW 2005) categorizes redband trout in the Malheur Lakes basin as potentially at risk of extinction due to habitat fragmentation and a relatively high number of disconnected populations. The Status Report also documented a lack of information pertaining to population level productivity. The lack of reliable data prevents the effective management and conservation of fish populations therefore the report considers a lack of information as a potential risk factor. The status assessment was based on interim criteria as outlined in the Native Fish Conservation Policy. This conservation plan develops a suite of metrics specific to interior trout species and available data in order to better assess population status (Chapter 2).

Silvies River (Malheur Lakes) redband trout are designated as Strategy Species/Populations in ODFW's Oregon Conservation Strategy (ODFW 2006). A strategy species is defined as one that is 'low and declining' or otherwise at-risk. Strategy species are designated based on conservation need and opportunity and considered the state's highest conservation priority. The purpose of identifying these species is to prevent further decline and, where possible, to restore their populations.

### 1.3.2 Federal Status

The U.S. Fish and Wildlife Service (USFWS) was petitioned in 1997 to list Great Basin redband trout in southern Oregon, northern California and northwest Nevada as threatened or endangered under the Endangered Species Act (Rhew 2007, USFWS 2000). The petition cited habitat degradation, fragmentation, and competition and predation by non-native fish as threats significant to redband trout. The petitioners argued that these threats, combined with prolonged periods of drought, have resulted in a decline in fish abundance that threatens their continued survival. The USFWS findings published in 2000 determined that listing was not warranted for two primary reasons. First, since the last regional drought redband trout abundance had rebounded and moderate densities were recorded throughout their distribution. Second, restoration activities in some basins had significantly improved aquatic habitat condition.

## 1.4 Background

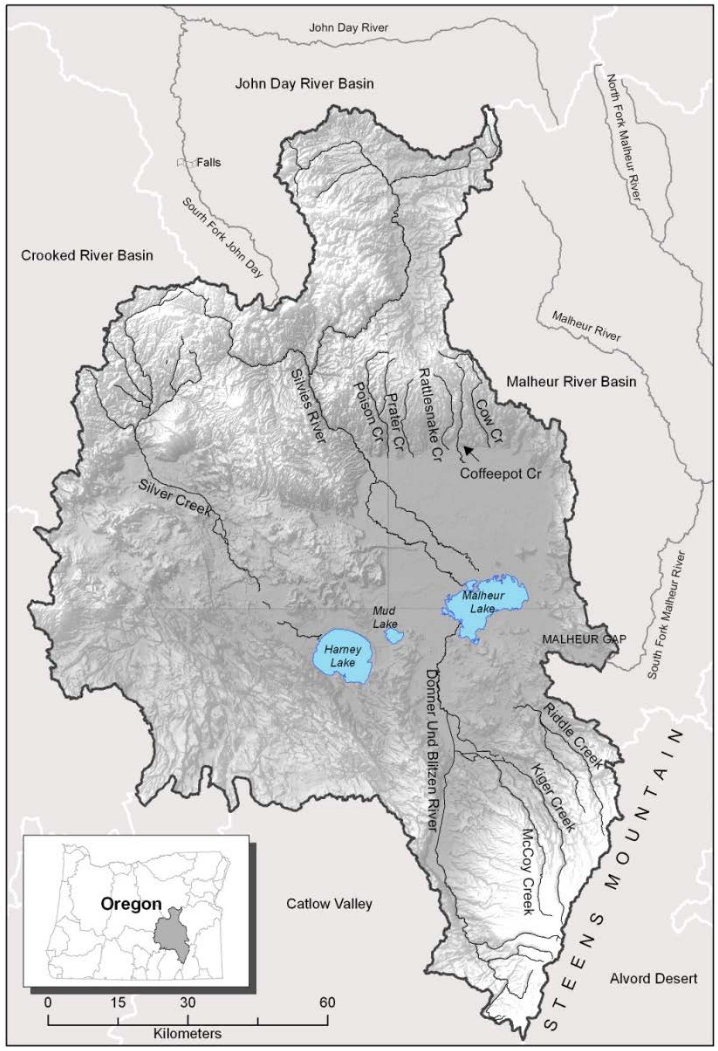
### 1.4.1 Biogeography – Oregon Portion of the Great Basin

The area covered by this plan is within the Oregon portion of the Great Basin – the northern-most portion of the Great Basin. The Great Basin is an area characterized by arid climate and closed watershed basins that do not drain into major rivers or oceans. These closed basins often drain into intermittent lakes, or playas, that allow a connection between streams only during wet cycles in the local climate.

#### 1.4.1.1 Malheur Lakes

The Malheur Lakes basin is the northernmost basin in the hydrographic Great Basin (Grayson 2011) and the largest interior basin in southeast Oregon. The basin contains three terminal lakes, Malheur, Mud and Harney Lakes, separated by shallow sills that interconnect during wet climate cycles and are filled by three major tributaries in the basin: Silvies River, Donner und Blitzen River, and Silver Creek. The Silvies and Donner und Blitzen (hereafter referred to as the Blitzen River) rivers, drain the greater part of the basin and flow into Malheur Lake (Piper et al. 1939). The Silvies River drains south at the southern end of the Blue Mountains, and the Blitzen River drains north off of the Steens Mountain. The headwater tributaries of these rivers are cold, swift, with coarse rock substrates whereas the lowland reaches are relatively slower and warmer, and with finer substrates. Highly alkaline Harney Lake is filled by Silver Creek and a series of warm water springs on the southwest shore. Isolated creeks bearing Redband trout dissipate into alluvial debris and natural meadows in the northeast (Poison, Rattlesnake, Prater, Cow & Coffeepot Creeks) and southeast (Smyth & Riddle Creeks) portions of the basin (Bisson & Bond 1971; Figure 1).

**Figure 1-1. Geography of Malheur Lakes Basin**




Although now considered part of the hydrographic Great Basin, the Malheur Lakes basin (also known as Harney Basin) was historically connected to the Columbia River. During the late Pleistocene epoch the Silvies River discharged through the Malheur River into the Snake River and on into the Columbia River. The Voltage lava flow blocked the Silvies River at Malheur Gap creating the shallow endorheic Lake Malheur (Hubbs and Miller 1948, Waring 1909). Additionally, a younger lava flow originating at Diamond Craters created the Barton Lake subbasin and isolated Smyth and Riddle Creeks from the Blitzen River (Minckley et al. 1986, Bisson & Bond 1971, Piper et al. 1939). The post glacial climate of the Great Basin varied over long periods. An interval of cool and moist climate was followed by a period of slow warming and then a period of generally high temperatures and desiccation. Lake Malheur receded during the latter hot period, 8 – 4,000 years ago, ultimately isolating many small streams from their connections with the pluvial lake (Minckley et al. 1986).

Fish fauna of the Malheur Lakes basin likely originated from tributaries of the Columbia River through two distinct invasions. Connection to the Malheur River during the Pleistocene provided opportunity for Columbia River species to colonize the Malheur Lakes Basin. The current fish assemblage in the Blitzen River, upland tributaries of the Silvies, and hydrographically isolated creeks closely resembles that of the middle or upper Snake River (Bisson and Bond 1971) and includes redside shiners, a form of mottled sculpin, redband trout and whitefish. Bisson and Bond (1971) demonstrated a second and later invasion from the John Day River (lower Columbia), probably through stream capture. Populations similar to those in isolated areas of the Malheur Lakes basin also exist above the barrier falls in the South Fork of the John Day River.

### 1.4.2 Ecoregion and Climate

The Malheur Lakes basin includes portions of two major physiographic provinces (USGS). The northern portion of Malheur Lakes Basin is within the Blue Mountains Ecoregion which is characterized by a complex of low elevation and open mountain ranges that are volcanic in origin. Much of the Blue Mountains are grazed by cattle. The southern portion of Malheur Lakes Basin is within the Northern Basin and Range Ecoregion. This ecoregion consists of tablelands that are dissected by lava plains, valleys, alluvial fans, and scattered mountains. It is higher and cooler than neighboring regions. Non-mountain areas have sagebrush steppe vegetation and cool season grasses. Ranges are covered in mountain sagebrush, mountain brush, and Idaho fescue at lower and mid-elevations; Douglas-fir, and aspen are common at higher elevations. Rangeland is common and dryland and irrigated agriculture occur at low elevations.

The climate of the Malheur Lakes basin is typical of a high elevation desert with generally low precipitation, mild summers and cold winters. Mean summer high temperature in Burns is 85°F, with extreme high temperatures reaching up to 102°F (Oregon Climate Service OCCRI). High temperatures at higher elevations on the Steens Mountain and in the Blue Mountains are considerably lower. Mean winter low temperature in Burns is 14°F with extremes down to -28°F. Though unrecorded, minimum temperatures on Steens Mountain are undoubtedly much colder.

Precipitation varies markedly with elevation, season, and water year. Mean annual precipitation in Burns is approximately 11 inches and 40-54 inches at high elevations (NRCS). Approximately 46% of the precipitation falls between November and March. Less than 25% of the annual precipitation falls during the growing season (July – September) and typically occurs as thunderstorms. Average annual snowfall in Burns is 40 inches (Oregon Climate Service). At lower elevations snowfall generally melts relatively quickly after a snowstorm, but at high elevations on the Steens Mountain snow cover can last year-round.

The hydrograph is characteristic of a spring-melt system, where peak flows occur in the spring during snow melt (OWRD, USGS) (Figure 1-3). Peak flow for rivers flowing off the Blue Mountains is earlier than that of rivers flowing off of the Steens Mountain because the higher elevations in the latter retain snow pack longer into the spring. Rain-on-snow events are common during the spring months when temperatures are increasing. Flows are lowest in the late summer months and may rise and fall quickly in response to intense thunderstorms.

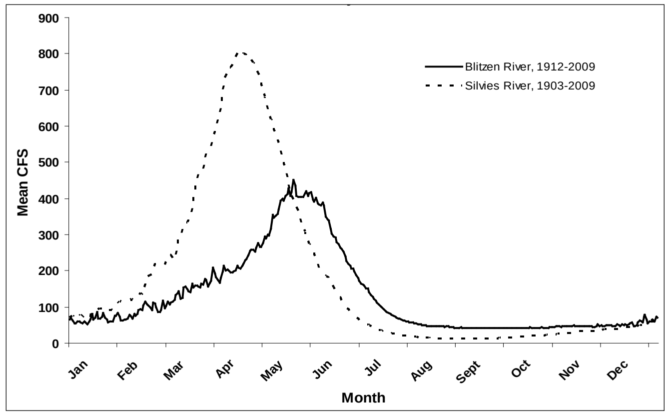


Figure 1-3 Mean daily flow for Blitzen and Silvies Rivers in the Malheur Lakes Basin. Data captured from USGS and OWRD.

Mean annual flows fluctuate considerably with water year. Extreme wet and dry years are natural phenomena characteristic of the high desert. The most recent wet years were 1981-1986 when the Malheur Lakes flooded. Other notable wet years were 1790-92, 1802-25, and 1907-13. Alternatively, the driest period on record is 1928-1934 when the Malheur and Harney lakes dried almost completely. 1842-49 and 1977 were also significant dry years (Figure 1-4).

### 1.4.3 Redband Trout Life History

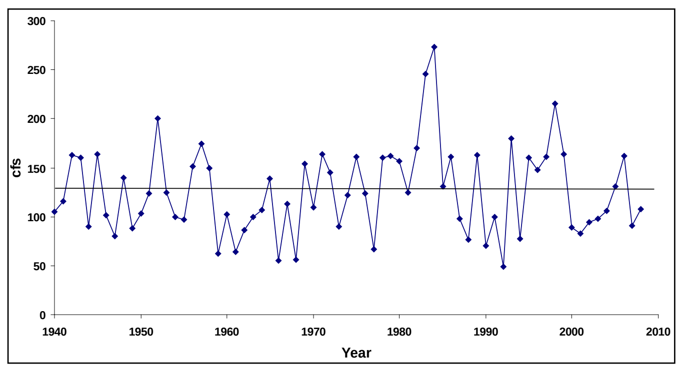


Figure 1-4 Mean Annual Flow for the Blitzen River, 1940 -2010

The life history of redband trout is extremely variable enabling the species to exploit a wide variety of habitats and conditions. In general, redband trout typically spawn in the spring when water temperatures are rising to above 6-7° C (Schill et al. 2009, Behnke 2002), though some populations occupying large spring fed streams spawn almost year around because the water temperature is cold and consistent (Li et al. 2007). Eggs remain in gravel for 4-7 weeks (Sigler and Sigler 1987), hatching in late spring or early summer. Typically, redband trout mature and spawn in 2-3 years, though males may mature one year earlier, and repeat spawning is common in many populations (Schill et al. 2009, Behnke 2002). An average generation time of three years was estimated for redband trout in this plan.

Migratory life histories of redband trout are also highly variable. Throughout their range there are examples of redband trout expressing one of many life history types; anadromous (migrating to and from the ocean), adfluvial (migrating between lakes and streams), lacustrine (inhabiting and spawning in a lake), fluvial (migrating between larger and smaller streams), and resident (residing in only one stream) strategies. In the Malheur Lakes SMU specifically, redband trout generally express one of three migratory behaviors. The stream resident form is the predominant life history strategy in all populations. Resident trout remain in smaller tributary streams for their entire life cycle, never out-migrating to larger more productive habitats to rear and mature. In small systems (less than 35 stream kilometers of fish distribution), such as the disjunct streams east of Burns (Rattlesnake, Prater, Cow, Coffeepot and Poison creeks), that do not have hydrologic connection to larger rivers and lakes, the habitat is capable of supporting only a resident life history type. Adfluvial and fluvial migratory forms are suspected to exist in most other populations when habitat conditions are suitable (Bowers et al. 1999). An adfluvial fish is one that spawns in small headwater streams and migrates to a large productive lake to rear and mature; a fluvial fish migrates to larger stream and river habitats to rear and mature before returning to its spawning reaches upstream. Currently, only redband trout in the Blitzen River have consistent access to Malheur Lake to rear. Redband trout in Silver Creek and Silvies River have the potential to express a migratory life history when conditions in connected rivers/streams allow.

### 1.4.4 Fisheries

Based on ethno historical records the original and historical Burns Paiute Indians were dependent on salmon, steelhead and other native fish as part of their total subsistence pattern (Couture 1996). Tribal fishing grounds were extensive and widespread, ranging as far as the Cascade and Wallowa Mountains and the Owyhee River. While the Malheur River (Logan Valley) and the John Day River were some of the primary fishing grounds for the Burns Paiute, they also fished in the Blitzen River, Silvies River, Camp Creek and local lakes such as Fish, Delintment and Yellow Jacket lakes. The annual timing of the Burns Paiute Indian migration depended on the seasonality and availability of specific food resources. In the 'cold month' (Dec. – Jan.) when snow covered the high elevations, they fished the Blitzen River and Malheur Lake (Couture 1996).

Redband trout in the Malheur Lakes SMU have not been subjected to any known commercial harvest. However, there are historical accounts from 1914-15 of efforts made by ranch hands to collect large numbers of redband trout from the Blitzen River for food. In the spring individuals would place traps in the spillway of irrigation dams capturing a trap full of 20 to 30 inch trout overnight (Haines, personal communication, as cited by Hosford and Pribyl 1983).

Recreational harvest has occurred since European settlement around 1870 (HCWC 2000). The first recorded capture of a trout in the Malheur Lakes basin by Europeans occurred in 1875. Captain Charles Bendire, of the U.S. Cavalry, fished Malheur Lake and observed trout up to 5 lbs. (Bendire 1875 as cited by Hosford and Pribyl, 1983).

Today redband trout provide multiple recreational fishing opportunities in the Malheur Lakes subbasin. Current regulations allow year-round angling with artificial flies and lures and the possession of 2 fish per day in streams and 5 fish per day in lakes. Both lakes and streams have length restrictions of a minimum of 8 inches and only one greater than 20 inches. In the Malheur Lakes Basin, bait angling is allowed in the Silvies River and Silver Creek subbasins as well as Rattlesnake Creek and tributaries. Stream and lake angling is open year-round in the Silver Creek and Silvies River subbasins. Some protective restrictions have been implemented in southern portions of the Malheur Lakes subbasin (Blitzen River and tributaries). The Blitzen River through the Malheur National Wildlife Refuge is closed to angling below the confluence with Bridge Creek. Above the Refuge (Page Springs Dam), in the upper Blitzen River basin, streams are open to catch and release year-round and gear is restricted to artificial flies and lures. Tributaries to the Blitzen River are regulated by the Southeast Zone regulations (Oregon Sport Fishing Regulations, 2018).

Statistical angler checks have not been conducted in many years, but periodic angler checks indicate that the most popular redband trout fishery is on the Blitzen River and tributaries. The Blitzen provides a unique opportunity to catch the prized, large, migratory redband trout in a high desert wilderness setting. In addition, the Steens Act (2000), which included Wilderness designation and development of the Redband Trout Reserve, has drawn nationwide attention to angling opportunities on the Blitzen River (T. Walters - ODFW, personal communication).

### 1.4.5 Hatchery/ Stocking

Historically planting of non-native rainbow trout occurred extensively throughout the Malheur Lakes basin. In particular, hatchery origin rainbow trout were heavily and frequently stocked in the Blitzen River, Emigrant and Bear creeks and the Silvies River of the Silvies subbasin, and Silver Creek, Poison and Rattlesnake creeks (ODFW Hatchery Stocking Records). Rainbow trout stocking activities have been discontinued in rivers and streams. The stocking program ceased in moving waters in 1973 in the Silver Creek sub-basin, 1992 in the Blitzen River sub-basin, and 1993 in the Silvies River sub-basin. Only standing water bodies are currently planted with coastal rainbow trout and include Krumbo Reservoirs, Fish Lake and the BLM stock ponds in the Blitzen River Subbasin, Yellowjacket Lake in the Silvies River Subbasin and Delintment Lake and Moon and Chickahominy reservoirs in the Silver Creek subbasin. Stocked fish are thought to be unable to escape from these water bodies and therefore will not mix with native stream dwelling trout. Beginning in 2007, most rainbow trout stocked in these locations have been triploid and therefore are considered sterile.

## 1.5 SMU and Constituent Populations

### 1.5.1 Species Management Unit (SMU)

The Oregon NFCP identifies that native fish will be managed at the species management unit (SMU) level. The NFCP defines an SMU as “a collection of populations from a common geographic region that share similar genetic and ecological characteristics.” The Malheur Lakes SMU covered by this conservation plan and its constituent populations are described below.

The geographical boundary of the Malheur Lakes redband trout SMU is defined as the watershed divide for the interior basin of Malheur and Harney Lakes (Figure 1-1). Streams, and therefore populations, within the SMU do not have hydrologic connection to the ocean or any other water body outside the basin.

The SMU is comprised of nine populations, all delineated by the limits of potential habitat available to each. By virtue of the fragmented nature of the stream systems within the basin, all populations are considered to be reproductively isolated and, therefore, independent. Exchanges between three intermittently connected populations are rare and depend on the occurrence of unusually wet climate cycles. If exchanges do occur they do not substantially affect population dynamics or extinction risk.

One population exists in each of the three major stream systems in the basin, Silver, Silvies, and Blitzen. The Blitzen population occupies the Blitzen River sub-basin and has relatively regular connection to Malheur Lake. The Silvies and Silver populations have potential to access Malheur and Harney Lakes respectively, but are excluded from the lower portions of those rivers due to irrigation activities and associated structures. Under current conditions, interchange of fish between these three populations is highly improbable and can only occur during extremely wet climatic conditions when high water levels connect all three lakes. Harney, Mud, and Malheur lakes were last connected during the early 1980's when water levels had reached a 150 year high. Also potentially preventing movement of redband trout between these three populations is a large barrier between Harney Lake and Mud Lake designed to prevent the movement of non-native Common Carp (*Cyprinus carpio*) between major river basins (OWEB 2007). This retaining wall may be breached during high water years when sufficient water reaches the valley floor. There is an artificial barrier between Malheur Lake and Mud Lake designed to keep carp segregated and consists of vertical steel bars with ½ inch gaps between them.

Five populations of redband trout exist in streams that naturally dissipate onto the Harney Valley floor. Poison, Prater, Coffeepot, Rattlesnake and Cow populations occupy short, small streams that drain King Mountain northeast of Burns. These populations all have extremely limited distributions primarily due to the isolated nature of the streams and the arid climate. The Riddle population occupies Riddle, Smyth and Paul creeks that flow north off of the Steens Mountain. This population is naturally isolated from the Blitzen population by an ancient lava flow that originated near Diamond Craters (Minckely et al. 1986).

It is important to note that the population in Prater Creek has not been verified by recent field sampling. It is included in this conservation plan strictly based on Bowers et al. (1999) which mentions it as a stream occupied by redband trout. Occupancy data supporting Bowers et al (1999) have not been found and recent field surveys have not documented redband trout in Prater Creek (ODFW Native Fish Investigations Program). However, a majority of potential redband trout habitat in Prater Creek is located on private property to which ODFW does not have permission to access. To err on the side of caution, this conservation plan treats redband trout in Prater Creek as an existing population until quantitative field sampling verifies absence with certainty.

The Native Fish Status Report (ODFW 2005) identified McCoy Creek as a separate population. This population occupies McCoy, Cucamonga, and Kiger creeks and currently has one-way connection to the Blitzen population. An impassable culvert prevents fish from moving from the Blitzen River upstream into the McCoy Creek system; however fish in the McCoy population are able to move downstream into the Blitzen River. Recent genetic analysis (DeHaan et al. 2015) found the McCoy Creek fish to group very closely with the Blitzen fish. As a result, this conservation plan considers the McCoy population to be part of the Blitzen population and efforts to re-establish two-way connection between the McCoy Creek and Blitzen River is a recommended conservation action.

### 1.5.2 Geographic Strata and Core Populations

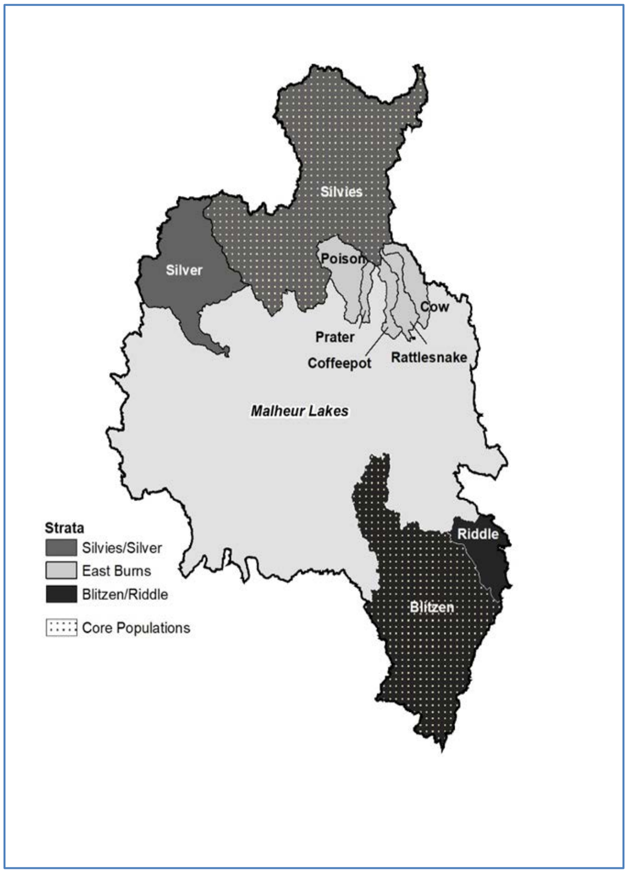



**Figure 1-5. Strata and core populations for Malheur Lakes Redband Trout SMU.**

In order to better define SMU status and describe potential genetic variation in general, the Malheur Lakes SMU is separated into three geographic strata based on differences in geologic features, elevation, precipitation, and geographic location. All populations in each stratum are similar in character relative to these attributes. The Silvies/Silver stratum is comprised of Silver Creek and Silvies River; the East Burns stratum includes the five small populations east of Burns – Poison, Prater, Coffeepot, Rattlesnake and Cow; and the Blitzen/Riddle stratum, the southern end of the SMU, is comprised of the Blitzen and Riddle populations (Figure 1-5).

Core populations are also identified in Figure 1-5. Core populations are defined as those populations that were historically larger, are more resilient, and are a likely source of colonizers into other population areas. The redband trout populations in the Silvies and Blitzen Rivers are identified as core populations for the Malheur Lakes SMU. These two populations are considered most resilient based on current abundance and productivity measures, and given their distribution they potentially include the greatest range of genotypic and phenotypic diversity.

# CHAPTER 2

# CURRENT STATUS OF THE SMU

## 2.1 Introduction

This chapter describes the current status of Great Basin redband trout populations in ODFW's Malheur Lakes SMU. To understand the current status of the redband trout populations, an assessment using measurable criteria is necessary (ODFW 2002), and some standard needs to be established to compare the results against in order to put the results into context. A definition of viability in terms of a set of measurable criteria was developed for the assessment conducted here and is described below. Greater detail on the assessment and criteria as well as the population–specific results can be found in Appendix 1.

The current status assessment serves as the starting point of the conservation planning process in which SMUs, strata and populations are identified that are not viable or do not achieve levels of desired status. For such SMUs, strata or populations, the status assessment provides the basis for identifying limiting factors and threats to be addressed by specific conservation actions. Given that all SMUs, strata and populations are rated using the same metrics and protocols, conservation actions can be easily prioritized within and between strata and/or populations. Additionally, this analysis identifies data gaps where more empirical information is necessary in order to fully describe population dynamics and more accurately assess status.

Population viability is defined as the balance between the rate of recruitment and rate of loss in a population such that the probability of persistence for a population remains constant or increases over a given period of time. Furthermore, the definition of viability, as employed by this plan, implies a population exists at such a level where the natural ecological and evolutionary processes can continue to operate through time (Fausch et al. 2006). A viable population has a negligible risk of extinction due to threats from demographic variation, local environmental variation, and changes in genetic diversity (McElhany et al. 2000). A population at high risk of not being viable is one where the probability of persistence is quite low and the population may potentially go extinct, whereas a population at low viability risk has a high probability of being viable through time. For this conservation plan, the time period of concern is the next 100 years. While somewhat arbitrary, 100 years represents a period long enough to encompass essential long-term processes (e.g. environmental cycles, genetic processes, and results of recovery actions) but short enough to appropriately model and evaluate population trends (McElhany et al. 2000).

ODFW's NFCP (ODFW 2002) recommends a suite of biological attributes by which to assess the status and viability of all native fish populations. These attributes include distribution, abundance, population diversity, connectivity, survival, population growth and a forecast of persistence. Commonly, conservation plans will evaluate some of these attributes collectively using a population viability analysis (PVA) in which ecological relationships and demographic parameters are incorporated into a mathematical model that predicts population trend and extinction probabilities. Such an approach provides a quantitative evaluation of risk with a measure of uncertainty. A robust PVA requires long-term datasets describing a population's life-history, population dynamics and habitat use, all of which are unavailable or inadequate for Oregon's Great Basin redband trout populations. Thus an accurate and reliable forecast of population persistence is not feasible. Instead, population viability in this plan is assessed using a suite of metrics incorporating many of the recommendations and guidelines outlined in McElhany et al. (2000). A guiding document for the conservation of salmonid populations, the McElhany et al. (2000) document describes four Viable Salmonid Population (VSP) attributes by which to effectively assess viability; abundance, productivity, spatial structure, and diversity. Although McElhany et al. (2000) made recommendations specifically addressing anadromous forms of salmonids, the biological principles therein are also fundamental to non-anadromous species. Many of the population attributes identified in the NFCP are captured within the four VSP parameters. Distribution and connectivity are elements of spatial structure, whereas population growth and survival are aspects of productivity.

The suite of metrics developed to assess Great Basin redband trout populations minimally examines the four VSP parameters while maximizing the limited empirical data and supplementary information available (Appendix 2). For example, in the absence of datasets directly pertinent to recruitment, productivity is evaluated using a length frequency analysis of fish captured during abundance sampling. In this case the metric is assessed using surrogate measures based on empirical data. Thus while a number of the metrics are not direct measurements of each criteria the biological attributes are retained.

The population viability analysis was objective, repeatable and transparent; however the results do not provide a quantitative measure of risk and an associated degree of certainty. Instead, risk was evaluated qualitatively based on the following basic tenets identified by McElhany et al. (2000):

- Larger numbers of individuals is better than smaller numbers,
- High reproductive rates are more secure than lower rates,
- Connected is better than isolated, and
- More diverse is better than less.

This population status assessment represents our most informed attempt at describing population viability. The data gaps and assumptions identified therein results in a high degree of uncertainty. Thus, this assessment and the metrics employed are intended to serve as a starting point for an iterative process to further refine the assessment methodology. The data gaps and uncertainties identified within this assessment will guide current and future research to provide assistance in determining meaningful metrics, defining appropriate thresholds and efficiently collecting pertinent data, all of which will result in a more accurate, meaningful and robust assessment in the future.

## 2.2 Population Viability Criteria

Criteria were developed based on the four VSP parameters outlined by McElhany et al. (2000): abundance, productivity, spatial structure, and diversity.

2.2.1 Abundance

The goal of the abundance criterion is to identify populations at high risk of suffering the deleterious effects of small population size. A viable population must be large enough to avoid the effects of inbreeding, survive environmental variation, be resilient to disturbance and maintain historical spatial structure. Unfortunately, data are not available to adequately determine a minimum threshold above which a population is not subject to these effects. Given this data gap, this conservation plan has established a minimum abundance threshold of 2,500 individuals based on widely accepted findings in the conservation literature, modeling exercises, empirical research on redband trout and other trout species, and best professional judgment (Appendix 2). In addition, data sufficient for accurately estimating population size do not exist for all populations. Some populations are characterized only by a handful of density estimates, thus the metric includes a framework to rank risk according to mean density while acknowledging the high degree of uncertainty associated with such an evaluation.

**Table 2-1 Objective – Maintain a population size > 2,500 age 1+ fish and a density > 50 fish/mile**
**Metric – Abundance and density of age 1+ fish**

| Fish / mile | Risk | Score |
|---|---|---|
| > 400 (248 / km), total pop >2500 | Very Low | 5 |
| 50 - 400, total pop >2500 | Low | 4 |
| < 50 (31/km), total pop >2500 | Moderate | 3 |
| < 50 (31/km), total pop <2500 | High | 1 |

The abundance metric was evaluated using a 2008 dataset designed to estimate population level distribution and abundance (Miller et al. 2010). Drawing from a sample frame of potential distribution, approximately 30 sites were surveyed in each population. Sites were randomly selected and spatially balanced to ensure a representative sample. Estimates of redband trout density were obtained at each sample site and extrapolated to the extent of the sample frame to obtain an overall approximation of population size with measures of confidence (Miller et al. 2010). Due to extremely limited distributions (<20 km), Miller et al. (2010) combined seven populations into two separate strata for logistical reasons. Evaluation in this plan of abundance for these populations was based on less robust abundance estimates, a measure of mean density, and/or professional judgment. Justifications for these judgment calls are outlined in the population results in Appendix 1.

2.2.2 Productivity

The intent of the productivity criterion is to identify populations in which productivity rates do not support net replacement or are not large enough to allow the populations to rapidly return to abundance targets after short-term perturbations. Ideally, this plan would assess productivity using a measure of population growth rate over the entire life cycle and, in the best of all circumstances, also include measures of stage specific productivity (McElhany et al. 2000). In regard to Great Basin redband trout populations, data are not available to directly assess productivity rates and quantify population growth. Trends in abundance do not exist at the population scale, and at the SMU scale reliable abundance estimates only exist for years 1999 and 2007-10 (Dambacher et al. 2009, Miller et al. 2010). These data are not adequate to evaluate long term trends and fluctuations in population abundance and productivity in light of natural climatic cycles. In the absence of typical measures of productivity, length-frequency histograms are employed as a general indicator of potential population growth (Appendix 2). While length frequency analysis does not provide an absolute measure of population replacement, it can identify instances when recruitment may be diminished. Populations in which the proportion of fish <100mm is continually low, may be suffering from sustained declines in recruitment that could translate into detectable declines in abundance. Similarly the absence of large adults could suggest a loss of significant life history traits, compromised long-term survival, and provides an indication of potentially decreased productivity. In lieu of an empirical measure of productivity, length frequency analysis is employed to identify populations of concern that warrant further evaluation.

The productivity metric considers the proportion of the population in two size classes, < 100mm and >200mm. Length at maturity for these populations is unknown and likely varies widely between populations. Based on research in the high desert of Idaho (Schill 2009) this assessment assumes fish <100mm are juveniles and fish >200mm are mature (Appendix 2). Populations are scored according to the proportion of the fish sampled <100mm and the proportion of fish >100mm that are > 200mm (sensu Zoellick *et al.* 2005). A population is first scored according to the percentage of juveniles. A point is added to or subtracted from that score if the proportion of fish >100mm that are >200mm is greater than 15% or less than 7% respectively.

**Table 2-2 Objective – Maintain a minimum proportion of juveniles and large adults, indicative of long term survival and reproductive success.**
**Metric – Proportion of population in smallest (<100mm) and largest (>200mm) size classes.**

| % of fish <100mm | Juvenile Score | % of fish >100mm that are >200mm | Adult Score | Risk | Final Score |
|---|---|---|---|---|---|
| >25% | 5 | > 15% | +1 | Low | 5 |
| 25 - 15% | 3 | 15 – 7% | 0 | Moderate | 3 |
| <15% | 1 | < 7% | -1 | High | 1 |

The productivity metric was evaluated using size frequency histograms of fish captured during 2007-2010 population sampling (Miller et al. 2010). Incorporating multiple years of sampling into the analysis mitigates the effect of temporal or spatial fluctuations in populations and sample timing (Platts and Nelson 1988, sensu Zoellick 2005). This analysis does not provide a measure of confidence. Instead, the sample size, both in terms of the number of fish and number of sites visited, serves as an indicator of certainty. Measurements from populations sampled with a large sample size are assumed to have a higher degree of certainty than those with a small sample size. In populations where data are not available or sample size was particularly low, the productivity criterion was evaluated based on best professional judgment. In these instances, intrinsic potential of the habitat, prior sampling (pre-2007), and anecdotal observations were taken into account. Justifications for these judgment calls are outlined in the results in Appendix 1.

2.2.3 Spatial Structure

The goal of the spatial structure criteria is to identify populations where alterations to the historical physical template negatively impact the natural spatially mediated processes necessary to maintain population level diversity and viability. Given that little information is available on how spatial structure relates to salmonid viability in general (McElhany et al. 2000) and biologists are unable to describe the spatial structure of redband trout populations specifically, this plan has developed a composite metric to assess the potential for a complex structure to exist (Appendix 2). The intent is to identify and conserve processes, such as dispersal, life history, and linkages between landscapes that likely contribute to persistence regardless of the actual spatial structure exhibited by a population (Rieman and Dunham 2000). Thus, by nature, the metric primarily considers landscape-scale processes as opposed to empirical population-specific data. This status assessment assumes historical populations survived many years of environmental change and therefore must have had adequate structure and diversity to remain persistent. Therefore, when managing for persistence and viability the goal is to preserve elements of historical spatial processes since it is not known whether a novel structure is sustainable (sensu McElhany et al. 2000).

While the NFCP (ODFW 2002) calls for status criteria to be based on fish performance, the policy acknowledges that secondary criteria may be used when information on biological attributes are not available. The criteria developed for spatial structure were limited to such secondary criteria to serve as surrogates for assessing fish performance.

The viability criterion for spatial structure evaluates two components separately; habitat availability/suitability, and connectivity. Each component is comprised of 2 or 3 metrics assessing different facets of that component. The metrics are scored on a continuum where large, connected, populations in suitable habitats are assumed to be relatively persistent and those that are small, isolated, and in degraded habitats are at some risk of extinction (Rieman and Dunham 2000). Habitat availability is described by measures of quantity, quality and configuration, whereas connectivity considers the accessibility of historical distribution and presence of habitat suitable for rearing migratory fish.

*2.2.3.1 Habitat Availability*
**Objective** – Maintain natural distribution through habitat availability.

**2.2.3.1.1 Habitat Quantity**
This metric provides a measure of how much historical habitat is currently occupied. Following the guidelines provided by McElhany et al. (2000) the goal is to maintain the historical template of available habitat and ensure habitat patches are not destroyed faster than they are naturally created. Thus populations whose current distribution is equivalent to historical distribution are considered to be at very low risk of not being viable, whereas populations occupying less than 50% of the historical distribution are at high risk.

**Table 2-3 Metric** - **Percent of historical distribution currently occupied.**

| % stream distance | Risk | Score |
|---|---|---|
| > 90% | Very Low | 5 |
| 75-89 % | Low | 4 |

| | | |
|---|---|---|
| 50-74 % | Moderate | 3 |
| <50% | High | 1 |

Current distribution is based on the potential year around distribution as represented by the sample frame employed by ODFW's Native Fish Investigation Project (NFIP) (Miller et al 2010). The NFIP redband trout sample frame includes wade-able streams or reaches that are sample-able by backpack electrofishing and therefore may underestimate the actual potential distribution in basins where redband trout occupy larger rivers (Strahler 1952) year around. The sample frame is unverified in the few streams where sampling has not occurred due to a lack of access to private property. Current distribution is calculated as the proportion of the sample frame occupied during the 2008 population level sampling effort (Miller et al 2010).

Historical distribution of redband trout is virtually unknowable and therefore undocumented (Schill 2009). For the purpose of this assessment the current upper extent of redband trout is assumed to be very similar to that of 200 years ago. Historical distribution is defined as all naturally connected reaches between the current upper extent downstream to natural lakes or the point of natural dissipation. The uncertainty associated with this measure is quite high, particularly in smaller disconnected basins where the natural point of dissipation has been altered by climatic cycles and land use activities and in larger basins where historical secondary channels have been altered or eliminated.

**2.2.3.1.2 Habitat Quality**

High quality habitat is fundamental to the persistence of Great Basin redband trout. Habitat quality is assessed with a limiting factors habitat model, HabRate, which was developed by ODFW's Aquatic Inventory Project to assess potential quality of in-stream habitat for steelhead trout (Burke et al. 2010). HabRate is a logic-based model that evaluates survey reaches based on their suitability for each life history stage (spawning to emergence, 0+ summer rearing, 0+ overwintering, 1+ summer rearing and 1+ overwintering). It incorporates a collection of stream level habitat variables into a series of 'if-then' statements that evaluate potential limiting factors. A comprehensive literature review of steelhead and rainbow trout habitat requirements provided the basis for these criteria (Burke et al. 2010). While the model was designed specifically for steelhead trout in the Deschutes River Basin it was intended to be applicable to most basins of the Pacific Northwest. Given the depth of the literature review, the general lack of interior redband trout specific studies, and the varied habitat use by redband trout, the criteria as written for Deschutes Basin steelhead trout are considered the best starting point for Great Basin redband trout (Appendix 2). Future research concerning specific habitat needs will be incorporated into the model when available.

Model output provides a general habitat rating of good, fair, or poor for each life history stage at each survey reach. This habitat assessment incorporates spawning/emergence, 0+ summer, and 0+ winter rearing scores into a final habitat score (Appendix 2). A population is then described by the proportion of sample sites in each classification. Populations exceeding 50% of sites classified as in good condition are considered at very low –to-low risk of not being viable. Populations exceeding 30% of sites classified as poor habitat quality are considered at high risk of not being viable.

**Table 2-4 Metric – Percentage of habitat rated as in good, fair or poor condition based on the outcome of the HabRate model**

| Good | Fair | Poor | Risk | Score |
|---|---|---|---|---|
| 75% | Up to 25 % combine | | Very Low | 5 |
| > 50% | < 50% combine | | Low | 4 |
| <50% | > 70% | < 30% | Moderate | 3 |
| 0% | < 70% | > 30% | High | 1 |

The Planning Team chose to apply HabRate to the 2007-2010 dataset because it was the most current dataset available and representative at the population scale. All sites surveyed between 2007 and 2010 were incorporated into the model except for annual sites (sites visited each year) where only the most recent survey was included. Given that the sites are representative, the overall score can be extrapolated to potential redband trout distribution within each population.

**2.2.3.1.3 Habitat Configuration**

This metric addresses the inherent risk to the population associated with the natural configuration of the system in which it resides. A highly dendritic system is comprised of a large proportion of low order headwater streams which increases the potential for multiple spawning areas (patches), and is considered a risk-resilient configuration. A population occupying a linear stream system has limited ability to establish multiple spawning areas and is at high risk of extinction due to stochastic events.

The evaluation of the configuration of habitat considers both stream order and the number of tributary junctions. Stream order and the number and location of tributary junctions are indicative of the degree of bifurcation. Given the vagaries of digital stream mapping, particularly in small desert streams, neither measure is singularly adequate.

**Table 2-5 Metric – spatial arrangement of habitat patches.**

| Stream Order | # of Junctions | Risk | Score |
|---|---|---|---|
| > 5 | > 5 - Dendritic | Very Low | 5 |
| 4 | 3-4 | Low | 4 |
| 3 | 1-2 | Moderate | 3 |
| 1 - 2 | 0 (linear) | High | 1 |

The assessment of the configuration metric was based on the stream habitat considered to be available to each redband trout population. This is defined as the potential distribution (NFIP sample frame) plus any connected stream segments classified as perennial in the USGS National Hydrography Dataset (NHD 1:24K). The NHDPlus dataset provides a Strahler stream order classification for each stream system. In instances where the stream order and number of tributary junctions did not result in the same risk rating, the score was chosen based on best professional judgment, with care to error on the side of caution. For instance, populations where junctions occurred high in the system were rated at higher risk than those with the same number of junctions but lower in the system. Rationale for all judgment calls are outlined in the results in Appendix 1.

*2.2.3.2 Within Population Connectivity*

**Objective** – Maintain historical levels of connectivity.

#### 2.2.3.2.1 Accessible migratory corridors

Maintaining migratory corridors free from obstruction is a critical step in maintaining historical levels of connectivity. Natural rates of movement between subpopulations should not be substantially altered by human actions (McElhany et al. 2000). Barriers, or even partial barriers, change movement patterns and alter dispersal rates (Anderson 2009), which can potentially affect the long term persistence of a population. For Great Basin redband trout, irrigation structures, such as push up dams and irrigation weirs, are common impediments to migration. In addition, poor water quality, unscreened diversions and poorly constructed road culverts also impact movement patterns. Ideally this conservation plan could directly assess the impact of barriers on the migratory behavior of redband trout. Unfortunately, the number and location of many impediments to passage are undocumented largely due to lack of access to private property. Thus, a representative measure is employed where the distance of current migratory corridors is compared to the historical distance. The longest continuous stream segment uninterrupted by a known barrier within the entire basin is the unit of comparison and serves to represent connectivity within the population boundary. Populations in which the difference between current and historical corridors is greater than 50% are considered at high risk of being non-viable. It is important to note this metric is based on known barriers. Effects of suspected or unidentified (e.g. undocumented irrigation dams or poor water quality) barriers are listed as a research need.

**Table 2-6 Metric - Percent of current greatest continuous stream distance (i.e. w/o barriers) relative to that distance historically.**

| % of stream | Risk | Score |
|---|---|---|
| > 90% | Very Low | 5 |
| 75-89 % | Low | 4 |
| 50-74 % | Moderate | 3 |
| <50% | High | 1 |

Current and historical distribution, as defined previously (habitat availability metric), served as the basis for this criterion. Barriers included in this assessment were those identified in ODFW's Natural Resource Information Management Program (NRIMP) barriers dataset (ODFW 2012). This dataset describes the location, barrier type (i.e. dam, culvert, and weir) and status (passable, partial, blocked and unknown). All barriers except those classified as passable were considered to have an effect on the migratory behavior of redband trout. Data provided by Oregon Water Resources Department (OWRD) served as supplementary information. These data describe surface water diversion points as determined by water right certificates. In many cases they are undescribed and unverified. In instances where OWRD identified barriers that were directly relevant to this analysis, verification was provided by ODFW field staff.

#### 2.2.3.2.2 Potential for Migratory Behavior

Life history type potentially affects dispersal rates. Populations that express a larger migratory life history are more likely to move between suitable patches than populations that contain only small resident fish (<200 mm). Populations that have access to large water bodies capable of fostering the growth of large fish (>250mm) have a higher potential of expressing a migratory life history. These habitats are primarily lakes and large rivers (≥ $4^{th}$ order). Maintaining these habitats in places where they were historically present preserves the potential for retaining the historical spatial structure of a population. Populations are rated on the availability of suitable rearing habitat. The intent of this metric is simply to evaluate if habitat is available to foster a migratory life history. In some instances habitat may be available but is not usable 100% of the year, every year, or is inhospitable (e.g. occupied by carp). In cases where the quality of these habitats is compromised, risk to these populations is upgraded until habitat improvements create more consistently hospitable conditions. Human created lakes and impoundments are not considered as potential habitats for this evaluation.

**Table 2-7 Metric – Availability of potential migratory adult rearing habitat**

| Availability | Risk | Score |
|---|---|---|
| Available | Very Low | 5 |
| Available, but not habitable or assessable year around | Moderate | 3 |
| Not Available | High | 1 |

The evaluation of this metric is largely based on professional judgment. Rationale for each population is detailed in the results in Appendix 1.

*2.2.3.3 Spatial Structure Scoring*

A mean score is calculated for each component of the spatial structure criterion, habitat availability (quantity, quality and configuration) and connectivity (barriers and migratory habitat). Given spatial structure is maintained by both components (availability and connectivity), and without either component spatial structure may be compromised, the lowest (highest risk) of the two mean scores becomes the overall score for spatial structure.

2.2.4 Diversity

The degree of genotypic and phenotypic diversity can have a profound effect on population persistence and viability in the face of environmental change. A population with a highly diverse array of genotypes has a large capacity to respond to environmental variability which in turn buffers the population against short-term spatial and temporal changes in conditions. A highly diverse population can also exploit a wide variety of environmental and habitat conditions (McElhany et al. 2000). Ultimately, naturally diverse populations may have more stable dynamics, and hence be more viable in changing environments, than less diverse populations (Rieman and Dunham 2000). Incorporating a diversity criterion into an assessment of viability helps ensure the preservation of the underlying genetic resources necessary for a population to fully exploit existing ecological opportunities, adapt to future environmental changes, or simply maintain a sustainable status (WLCTRT 2006).

The goal of the diversity metrics is to identify populations where the significant loss of diversity may jeopardize long term viability. This conservation plan uses two metrics to assess diversity, the presence of multiple life history types, and an indirect measure of ecological diversity (Appendix 2). The intent is that the direct measure confirms a substantial degree of diversity, and that the indirect ecological measure will be representative of a finer examination when data regarding life history types are unavailable or uncertain.

*2.2.4.1 Phenotypic diversity – number of life history types*

**Objective –** Maintain phenotypic expression by maintaining known attributes of life history types

For Great Basin redband trout fine details describing the full spectrum of life history variation are unknown. In most populations, data specific to phenotypic traits (e.g. spawn timing and age structure) have yet to be collected. In fact, in most populations just the identification of simply a migratory or resident life history is the extent to which life history variation can be described. Therefore, the application of this metric reflects the level of resolution to which biologists can describe life history strategies expressed by a population. Thus this metric can only provide two risk categories. When more detailed life history data become available, then additional risk categories will be incorporated.

**Table 2-8 Metric – Life history diversity**

| Life history | Risk | Score |
|---|---|---|
| Multiple Life Histories | Very Low | 5 |
| Resident Only | Moderate | 3 |

Life history studies are rarely available for Great Basin redband trout. This plan assumes every population expresses a resident life history strategy at a minimum. The presence of a migratory component may be indicated by relatively large individuals (> 250 mm) or evidence of significant movement between spawning and adult rearing areas within the past 6 – 7 years (2 generations). For populations where life history information is unknown, the classification of the number of life history types expressed by a population is based on professional judgment.

*2.2.4.2 Ecological Diversity*

**Objective** – Maintain life-history expression by maintaining occupancy in a natural variety of available habitat types where a diversity of spatially-mediated processes occurs.

Diversity within a population is closely related to habitat diversity; where salmonid populations exhibit local adaptation to specific habitats they occupy (Crossin et al. 2004). As a result, variation in habitat types promotes the expression of a variety of phenotypes (Hendry et al 1998, Waples et al. 2001). Therefore, it follows, the greater the variation among available habitats, then the higher the probability for phenotypic and genotypic variation within a population (Neville et al. 2009).

This assessment relies on elevation bands to identify different habitat types encountered within the distribution of each population (sensu WLCTRT 2006). Habitats within various elevation categories are generally distinguished by stream order, gradient, and thermal regimes, all factors which influence local adaptation. To quantify reductions in diversity, comparisons are made between current and historical distribution of fishes within each elevation band. The metric calculates the average absolute change in proportion between current and historical distribution within each category.

**Table 2-9 Metric – Average cumulative % change in occupancy across elevation bands.**

| % Change | Risk | Score |
|---|---|---|

| | | |
|---|---|---|
| < 5% | Very Low | 5 |
| 6 - 10% | Low | 4 |
| 11 - 20% | Moderate | 3 |
| > 20% | High | 1 |

For this metric current distribution equates to the potential distribution as defined by the NFIP sample frame. Historical distribution is as previously defined for the habitat availability metric. The stream distance of current and historical distribution within 50m elevation categories was calculated using a GIS. The cumulative percent change was then calculated as follows:

$$\Delta ED = \frac{\sum_i |P_{Hi} - P_{Ci}|}{n}$$

where n = the number of elevation categories, i, $P_{Hi}$ = the proportion of the historical distribution in elevation category i and $P_{Ci}$ = the proportion of the current distribution in elevation category *i* (WLCTRT 2006). Defining current distribution as the potential distribution could misrepresent the degree of change. In basins where the currently occupied stream reaches are significantly different from the potential distribution the change in ecological diversity will be underestimated.

2.2.4.3 Diversity Scoring –

The final diversity score is calculated as the mean of the two metrics. This approach equally weights the two metrics and speaks to the significantly different aspects of diversity that each evaluates.

## 2.2.5 Assessing Viability Risk

The scores for the four viability parameters are combined to generate an overall rating of risk for each population. The mean score is calculated for abundance and productivity (A/P), as is the mean for spatial structure and diversity (SS/D) scores. The mean scores are then rated according to the decision matrix (Table 2-10). Given that spatial structure and diversity are believed to be as important to redband trout population viability as abundance and productivity, the combined A/P and SS/D scores are weighted equally when determining overall population risk.

An overall status assessment of moderate, low or very low risk is considered to equate to populations being viable (able to persist for 100 years or more). An assessment of high risk is considered to indicate populations that are not viable.

**Table 2-10. Status assessment decision matrix.**

| A/P (mean of the two scores) | Spatial Structure & Diversity (mean of the two scores) | | | | |
|---|---|---|---|---|---|
| | Risk | Very Low (5) | Low (4) | Moderate (3) | High (1) |
| | Very low (5) | Very Low | Low | Moderate | Moderate |
| | Low (4) | Low | Low | Moderate | High |
| | Moderate (3) | Moderate | Moderate | Moderate | High |
| | High (1) | Moderate | High | High | High |

### 2.2.6 Results

Of the nine redband trout populations in the Malheur Lakes SMU, one was rated at low risk (viable), six at moderate risk, and two at high risk (Table 2-11).

In general, population level abundance was much greater than the threshold estimated to identify populations at high risk of the deleterious effects of small population size. Of the seven populations evaluated with rigorous estimates of abundance, all but one were estimated to exceed the 2,500 fish >100mm. Two populations scored poorly for abundance; Prater and Cow (Table 2-11). Data pertinent to these populations was very limited, preventing a rigorous population estimate. The poor score primarily is due to a lack of recent observations of fish, or of fish at moderate densities.

Length frequency analysis suggests productivity is likely adequate to maintain net replacement in seven of nine populations. These populations contained a relatively high proportion of juvenile fish indicative of high recruitment levels. The proportion of fish > 200mm was variable among populations and rarely exceeded 10%. Two populations showed indications of poor productivity, Prater and Cow (Table 2-11). Again, the lack of appropriate data plays a significant role in the assessment results for these populations.

The population assessment shows the spatial structure of many populations is highly compromised. Only the Blitzen was rated as having low risk from spatial structure and just two were rated as moderate risk; Poison and Rock (Table 2-11). The remaining nine populations were scored at high risk for the metric. Generally, degraded habitat, passage barriers, and loss of historical habitat have negatively impacted the potential of populations to maintain their historical metapopulation structure.

Overall, the viability metrics reflect that most populations have likely maintained adequate levels of diversity. Prater Creek, the only population for which diversity was scored as at high risk, showed a significant loss of habitat that resulted in a relatively substantial decrease in ecological diversity. Life history diversity is also limited in most populations, where all populations except the Blitzen are assumed to contain only a stream resident form.

**Table 2-11 Population risk assessment results for Malheur Lakes SMU. (**Criteria scores in parentheses. * - Denotes core population. Strata denoted by shading. **)**

| Population | Abundance | Productivity | Spatial Structure | Diversity | Current Viability Risk |
|---|---|---|---|---|---|
| **Silver** | Very Low (5) | Low (4) | High (1) | Low (3.5) | ***Moderate*** |
| **Silvies*** | Very Low (5) | Low (4) | High (2.3) | Low (3.5) | ***Moderate*** |
| **Poison** | Very Low (5) | Low (4) | Moderate (2.7) | Low (4) | ***Moderate*** |
| **Prater** | High (1) | High (1) | High (1.7) | High (2) | ***High*** |
| **Rattlesnake** | Very Low (5) | Low (4) | High (2.3) | Low (3.5) | ***Moderate*** |
| **Coffeepot** | Moderate (3) | Moderate (3) | High (2) | Low (3.5) | ***Moderate*** |
| **Cow** | High (1) | High (0) | High (1) | Low (3.5) | ***High*** |
| **Riddle** | Very Low (5) | Moderate (3) | Moderate (2.7) | Low (4) | ***Moderate*** |
| **Blitzen*** | Very Low (5) | Very Low (5) | Low (3.7) | Very Low (5) | ***Low*** |

## 2.3 SMU Viability

The SMU is considered “not viable” when all populations except one in each stratum is assessed as at high risk, or when one core population is at high risk. In circumstances where a core population is assessed at high risk, conditions are likely present where the remainder of the SMU is in jeopardy.

## 2.4 Current Status Summary

The population risk assessment for populations in the Malheur Lakes SMU identified only one population (Blitzen) that was at low risk. Six of the nine populations in the SMU are at moderate risk, and two populations (Cow and Prater) were assessed at high risk. Most populations were not at high risk and both core populations were better than high risk, so the SMU is currently considered “viable”.

# CHAPTER 3

# DESIRED AND CRITICAL STATUS

## 3.1 Introduction

The goal of ODFW's NFCP is to conserve and restore Oregon's native fish to levels that can provide recreational, commercial, cultural and aesthetic benefits to present and future citizens. The NFCP relies on the statewide collection of conservation plans to present a roadmap describing how to achieve this goal, SMU by SMU. Thus each conservation plan must specify a level of desired status at which the SMU can offer the economic, ecological and cultural benefit required by the policy. One component of desired status includes measurable biological targets against which progress can be evaluated and success can be determined. These targets often relate to measures of viability and overall population status.

Similarly, conservation plans must identify thresholds, based on biological attributes, indicative of significant deterioration in status. These thresholds, collectively referred to as 'critical status', serve as a set of early warning indicators. Once a population or SMU reaches critical status it triggers an increase of recovery actions or plan modification in order to adequately address the limiting factors and stem the decline. The level of critical status must be avoided if possible. Much below this point the future viability of the SMU or the population is unpredictable.

## 3.2 Desired Status

The Planning Team developed a qualitative description of what should be the desired status for Malheur Lakes redband trout. This description of desired status will be presented to the public for their consideration and approval.

The overarching goal of the Malheur Lakes redband trout conservation plan is to maintain nine robust native redband trout populations with:

- Adequate abundance to retain genetic integrity during a dry climate,
- Adequate productivity to respond quickly to wet climate conditions,
- The ability to interact with other populations when natural conditions allow, and
- The ability to provide recreational angling and harvest opportunities within the basin.

To achieve the overarching goal for desired status, the Planning Team has identified that each population in the SMU must improve at least one risk category relative to their current status (e.g. change from low to moderate). A single population achieves desired status when it is assessed at a lower risk level (i.e. change from high to moderate). Relative to the current population assessment, population specific desired status goals are detailed in Table 3-1. At the SMU scale, desired status is achieved when all populations achieve their level of desired status. This definition of desired status is reflective of an overall improvement across the landscape and doesn't rely on one specific attribute or measure by which to evaluate success. This approach allows some level of flexibility as to which criteria to address in order to achieve a lower risk level. An examination of the limiting factors and threats (Chapter 4) for each population can provide a number of potential options to achieve desired status for each population.

**Table 3-1 Desired Status for populations in the Malheur Lakes SMU**

| Population | Current Viability Risk | Desired Status |
|---|---|---|
| Silver | *Moderate* | Low Risk |
| Silvies* | *Moderate* | Low Risk |
| Poison | *Moderate* | Low Risk |
| Prater | *High* | Moderate Risk |
| Rattlesnake | *Moderate* | Low Risk |
| Coffeepot | *Moderate* | Low Risk |
| Cow | *High* | Moderate Risk |
| Riddle | *Moderate* | Low Risk |
| Blitzen* | *Low* | Very Low Risk |

Ideally, desired status would be achieved when all populations are at low or very low risk. The Planning Team believes the definition of desired status above is a more realistic goal given the nature of the small isolated populations. The natural limitations (i.e. small basin size and natural lack of inter-population connectivity) characteristic of Prater and Cow populations create circumstances where a moderate risk of extinction is the most realistic goal.

## 3.3 Critical Status

The critical status level for this SMU is intended to be a level of risk at which the SMU is still viable, but is at high enough risk that it could become non-viable in the near future (10 to 15 years). A designation of critical status triggers the inclusion of the SMU on Oregon's Sensitive Species List as Critical. The level of critical status in this plan represents not only the point where expanded action must occur, but also the state of maximum acceptable loss of genetic variation across the landscape. Given the isolated nature of the populations within the SMU, genetic mixing between populations is virtually non-existent. Based on this, and analyses of genetically distinct *O. mykiss* populations in tributaries of hydrologically connected systems (Small et al. 2007), this plan assumes each population is adapted to local environmental conditions, and has led to measurable genetic distinction between populations while still sharing similarities with other populations in the SMU. Since functionally extinct populations cannot be naturally re-founded by individuals straying from other populations, the distinct locally-adapted genotype is then permanently lost. One of the primary goals of this plan is to retain the distinct genetic structure of each population, but to also manage SMU-level diversity in a manner that retains re-founding opportunities. For the purpose of this plan, the state of critical status is the highest level of acceptable loss that still preserves the range of genetic diversity of redband trout in each SMU.

Critical status for the Malheur Lakes SMU is defined (Table 3-2) as being reached when any strata contains only one population rated better (lower risk) than high risk. Considering the remarkable plasticity characteristic of redband trout and their apparent ability to persist through a wide range of climatic and environmental conditions, this plan assumes that once conditions are such that the SMU reaches critical status there is high potential for the same conditions to quickly affect the remaining lower risk populations. This level of critical status is indicative of large basin-wide conservation issues and likely represents a state below which the status of the SMU may rapidly degrade. At the population level, critical status is defined as being reached when a population is assessed at one level greater risk (worse condition) than currently assessed.

**Table 3-2 Desired, Critical and Not Viable status criteria at the population and SMU levels. Current status for populations are indicated in Table 2-11.**

| Status | | Population | SMU |
|---|---|---|---|
| | **Desired Status** | One level better (less risk) than current status. | All populations one level better than current status. |
| | **Critical Status** | One level worse (higher risk) than current status. | *Any* stratum contains only one population not at high risk. |
| | **Not Viable** | Population at high risk (3-4 VSP metrics failed). | *Each* stratum contains only one population not at high risk<br>**or**<br>Any core population at high risk. |

### 3.4 Determining Future Status

In order to determine future status of redband populations and the SMU in relation to desired and critical status, it will be necessary to re-assess risk status after a period of time (i.e., 12 years, or approximately four redband trout generations; see Section 7.3). Waiting to assess status again will eliminate year-to-year variability and ensure perceived improvements are long-lasting and not just due to temporary climatic or other conditions. The current, and likely future, limitations on ODFW staffing and funding will make it nearly impossible to annually collect the necessary status assessment data on all of the Malheur Lakes redband trout populations using criteria described in this plan.

The viability assessment criteria developed in this plan are based on an intensive study that took place in Oregon's Great Basin over a four-year period (2007-2010). The data collected in this study provided the most detailed information that has ever been collected on Oregon redband trout, their distribution and their habitat. Using these data and the criteria developed around them to assess the current viability of these redband populations provided the best picture of fish status – though with a fair degree of uncertainty.

It will be difficult to regularly repeat the intensive sampling that occurred in 2007-2010, therefore a critical research need of this plan is to develop a sampling approach that is less labor-intensive, that can be routinely implemented, and can provide information to assess the status of these populations (see Chapter 6: Research and Monitoring Needs). A related critical research need is to develop alternative assessment criteria that can be used with the data collected from the new sampling approach to assess improvement or deterioration of population status. These criteria would be cross-walked with the current status criteria identified in Chapter 2 so future status can be assessed against the desired status, critical status and non-viable status criteria described above. Until such time, ODFW will rely on personal observations and anecdotal information to track the status of redband trout in the Malheur Lakes SMU.

### 3.5 Current Status Compared to Desired or Critical Status

The NFCP calls for conservation plans to determine the gap between current and desired status. This gap then sets the stage for determining the factors limiting the SMU (Chapter 4) and the types of actions and quantity (Chapter 5) to implement in order to achieve desired status.

In Chapter 2 (Current Status) the redband trout populations and SMU were assessed based on the risk criteria developed. The criteria for desired status outlined above call for all populations in the SMU to be at one category lower risk than current status. The gap between current and desired status for all populations is therefore one risk category. The reasons behind this gap will be addressed in Chapter 4.

Application of the risk criteria found the Malheur Lakes SMU to be viable with two thirds of the populations (6 of 9) being at moderate risk, one population (Blitzen) at low risk, and two populations (Prater and Coffeepot) at high risk. Since none of the strata in the Malheur Lakes SMU have only one population better than high risk, the SMU is not at critical status. The criterion for individual populations in the SMU has not been met (status has not been assessed for three generations), so no populations are at critical status.

# CHAPTER 4

# LIMITING FACTORS AND THREATS

## 4.1 Introduction

This chapter describes the limiting factors and threats to the viability of redband trout populations in the Malheur Lakes SMU. A limiting factor is defined as the physical, biological, or chemical conditions and associated ecological processes and interactions (e.g., population size, habitat connectivity, water quality, water quantity, etc.) experienced by the fish that may influence the parameters of a viable salmonid population (VSP). Threats are defined as the human actions— habitat alterations, hydro system operations, fishing, hatchery operations, and predation—that *cause or contribute to* limiting factors.

Limiting factors and threats (LFTs) are considered throughout the entire redband trout lifecycle and across the landscape including areas of spawning, rearing and migration. Factors and threats are identified and ranked according to the severity of their impact on the VSP parameters of each population. This ranking serves as the basis for the development and prioritization of management and conservation actions. The intent is to focus conservation and restoration work on those actions that will yield the greatest beneficial effect on population sustainability.

## 4.2 Expert Panel Process

Limiting factors and threats were identified through an expert panel process similar to those implemented for other ODFW conservation and recovery plans. The Expert Panel consisted of eleven biologists with extensive knowledge of redband trout in general and the constituent populations of the Malheur Lakes SMU in particular. The panel represented multiple state and federal management agencies (ODFW, United States Forest Service (USFS), United States Fish and Wildlife Service (USFWS), and Bureau of Land Management (BLM)) and the Burns Paiute Tribe. At the outset of the process, panel participants individually identified and ranked limiting factors and associated threats according to significance at each life stage for each population. An initial list of potential key and secondary limiting factors and threats was developed from the results of these rankings. The panel then convened to consider and discuss this initial list. Arguments were made to support or refute the relative importance of factors for each population, often citing assessments provided by WNTI (May et al 2012), US Forest Service (USFW 2010), and the watershed council (HCWC 2000, 2001, and 2010). Based on panel consensus the list of limiting factors and threats was modified to reflect the general belief of the group.

It is important to note that since this process is based primarily on professional opinion rather than empirical information the certainty is quite limited. There is the potential of misidentifying limiting factors where some may be wrongly included, others may be missed, and the importance of others incorrectly ranked. While the effect of these limiting factors and threats may be conceptually apparent, the direct impact is not empirically described. In addition, the interactive or cumulative impact of all potential threats is not well understood. The relationship of limiting factors to specific threats is not always clear. For example, in many instances low water quantity may be indirectly due to land use, water management, natural conditions or a combination of all. In light of the high degree of uncertainty associated with the multiple pathways that threats can be manifested into limiting factors, it will be important to build strategies that are robust to uncertainty. This conservation plan presents limiting factors and threats as working hypotheses that are nested within specific strategies to address the LFTs, and which have measurable objectives. Strategy efficacy will be evaluated through research, actions, monitoring, and evaluation.

## 4.3 Limiting Factors and Threats

### 4.3.1 General Limiting Factor Categories

Table 4-1 details the categories often used to classify the various factors impacting redband trout populations. The Expert Panel selected from this list to identify the key and secondary limiting factors in the Malheur Lakes SMU.

**Table 4-1. General limiting factor categories and definitions**

| Category | Description |
|---|---|
| Water Quantity | Hydraulic Regime: changes in timing, duration and magnitude of flows. |
| Water Quality | Water characteristics including temperature, dissolved oxygen, suspended sediment, pH, contaminants etc. |
| Predation | Consumption of naturally produced fish by one or more species |
| Competition | Interaction between fish and other species or populations over food or space |
| Food Base | Amount, quality, and selection of food available for metabolic maintenance and growth |
| Disease | Pathological condition in naturally produced fish resulting from infection |

| | |
|---|---|
| Physical Habitat Quality | Quality of physical habitat including channel structure and complexity, channel morphology, riparian condition, large wood recruitment (where pertinent), sediment routing and upland processes |
| Habitat Access | Impaired access to spawning and/or rearing habitat including partial or complete artificial obstructions, delayed migrations, de-watered stream segments and access to on- and off-channel habitat |
| Other Factors | Factors affecting population parameters and individual fitness that are not addressed by other limiting factors including injury, genetic integrity, human take and population traits (e.g. low abundance limits pairing and reproductive success) |

### 4.3.2 General Threat Categories

This plan defines threats as the human actions that cause or contribute to limiting factors. A common example is that diversion dams associated with irrigation activities can impede redband trout access to habitat in the upper watershed during upstream spawning migrations. An individual threat may contribute to multiple limiting factors. In-stream water diversions are a good illustration where a water diversion can affect habitat access, physical habitat, water quality, and water quantity. The converse is also true, where one limiting factor is affected by multiple human caused threats. This is common in the Malheur Lakes SMU where in-stream water quality can be affected by carp (introduced species), riparian management and agricultural practices (land management), and water withdrawal (water management). In addition, past threats, such as grazing activities, can have long lasting effects and, while not currently in practice, their legacy may continue to contribute to current limiting factors.

Five primary threat categories were considered by the Expert Panel for the assessment: water management, land management, introduced species, harvest management, and hatchery management. These threats are summarized in Table 4-2. Threats associated with climate change will undoubtedly impact redband trout population viability now and in the near future. However, given that specific effects of climate change on individual populations are complicated and difficult to predict, this plan limits the discussion to generally describing potential impacts and their contributions to limiting factors *(see Appendix 3)*.

**Table 4-2. General threat categories and definitions**

| Category | Description |
|---|---|
| Water Management | Impact of hydropower, flood control, water withdrawal, and water storage systems. Specific threats may include dam and dike construction and operations, conversion of riverine habitat to reservoir, conversion of off- |

| | |
|---|---|
| | channel habitat, wetlands and floodplains to other uses, modification of water quality and sediment transport, and flow alterations. |
| Land Management | Impacts of past and current land use activities on naturally produced fish. Land use practices include timber harvest, agriculture, transportation, mining, grazing, and industry. This category includes both current land use practices that are causing limiting factors and impairing fish populations as well as current practices that are not adequate to restore limiting factors caused by past practices. |
| Introduced Species | Impact of non-native plants or animals on naturally produced fish or their habitat. |
| Harvest Management | Direct and indirect mortality associated with fisheries on naturally produced fish. |
| Hatchery Management | Negative impact of hatchery practices on naturally produced fish. Hatchery practices include: number of fish released, removal of adults for broodstock, breeding & rearing practices, release practices, water quality management, blockage of access to habitat etc. |

In the Malheur Lakes SMU threats associated with land management and water management are closely linked. Agricultural operations common in the low-land portions of most watersheds rely on various methods to collect and transport water from streams and rivers for irrigation and livestock purposes. This plan attempts to dissect threats associated with land management and water management but in many instances they can be viewed as one and the same.

Natural attributes such as fire, drought, or geology interact to create environmental regimes (including disturbance regimes) and play an important role in shaping demographic processes in the Malheur Lakes SMU. Human threats can alter the frequency and magnitude of these regimes and therefore demographic processes such as mortality.

### 4.3.3 Life-Stage and Geographic Areas

Life-Stage Definitions

This plan considers the impacts of limiting factors and threats throughout the entire life cycle of redband trout. For the purpose of this evaluation, the life cycle is categorized into four general life stages: juvenile, sub-adult, adult and spawner (Table 4-3). The early life and juvenile stages are collectively considered due to the uncertainty associated with the impacts on each stage specifically and the absence of life-stage specific data for all populations. The separate adult stages face the same general level of uncertainty; however the correlation between life stage and geographic area for migratory populations suggests a benefit to considering them separately.

**Table 4-3. Life stages definitions of redband trout.**

| Life Stage | Description |
|---|---|
| Juvenile | All life stages from egg to juvenile, specifically including egg, alevin, fry, fingerling, parr and juveniles. |
| Sub-adult | Rearing fish, age 1+. If migratory, migrating downstream toward, and residing in, larger rearing habitats |
| Adult | Maturing fish. If migratory, moving toward spawning grounds. |
| Spawner | Sexually mature fish, staging to spawn. |

Geographic Areas

Limiting factors and threats may vary across different geographic areas occupied by redband trout throughout their life cycle. This plan considers two general geographic areas that differ by location within the basin and habitat type; headwater tributaries and low land rivers and lakes (Table 4-4). These areas are delineated by the intersection between stream order and elevation where elevation serves as a convenient surrogate for slope. Each geographic area is generally utilized by different life history types and life stages of redband trout.

Distribution within a population is determined by connectivity, water year, and habitat suitability. Some populations are naturally limited to small stream habitats where larger, lowland habitats do not exist. Only a few populations have access to areas potentially suitable for fostering a migratory life history. Most populations addressed in this plan carry out their life cycle in a very limited geographic area (Figure 4.1).

**Table 4-4. Geographic area definitions and life stage they support.**

| Geographic Area | Description | Life Stage Occupied |
|---|---|---|
| Headwater/ Tributary | High elevation, upper basin stream; stream order = 1 – 3 | Juvenile, resident sub-adult and adult, spawners |
| Large River / Lake | Low elevation, low land habitats; stream order = 4 – 6 | migratory sub-adult and adults |

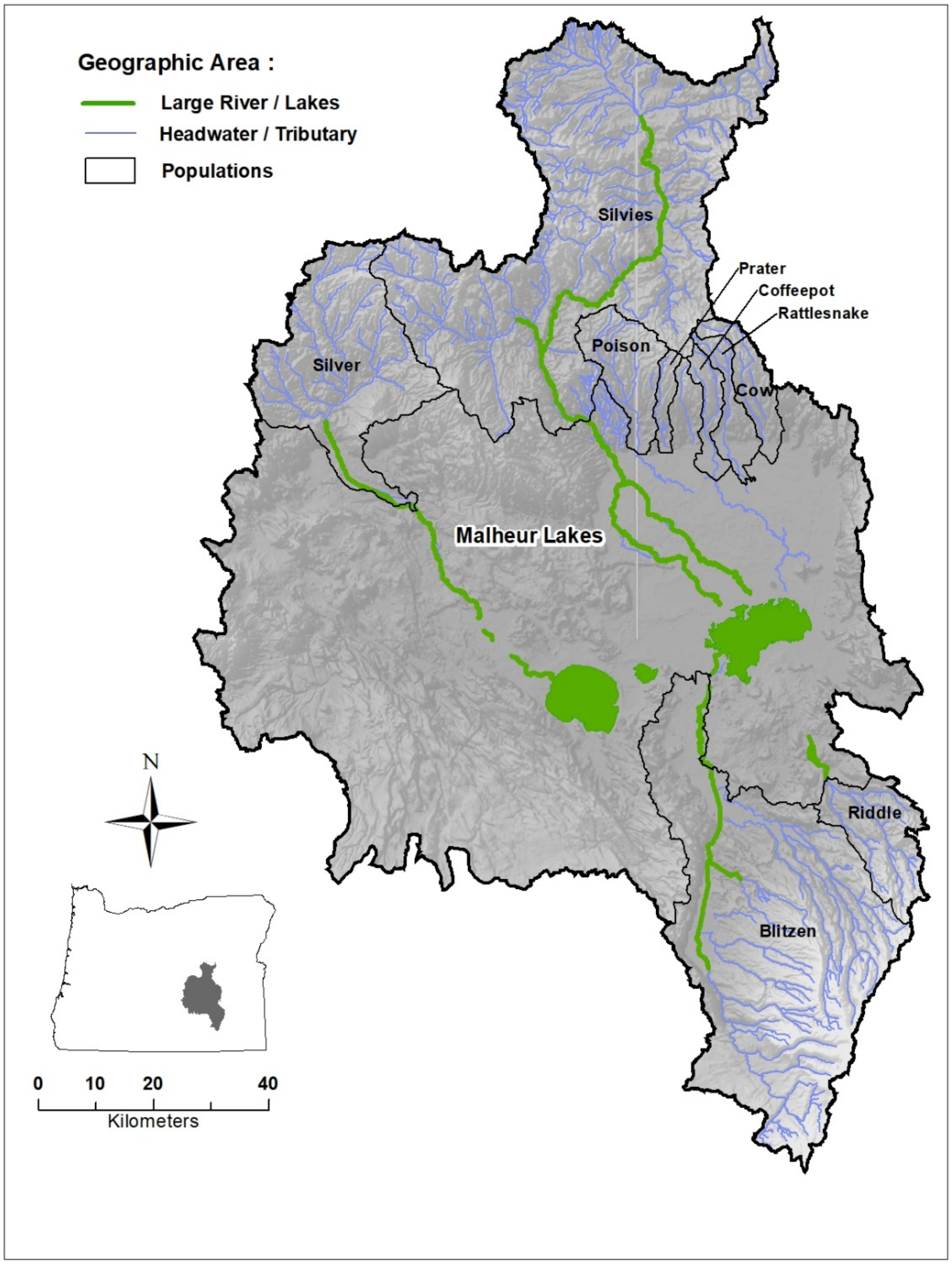



Figure 4.1. Geographic areas of Malheur Lakes SMU.

## 4.4 Overview of Common Threats and Associated Limiting Factors

This section describes the broad threats that were commonly identified as significant to most of the populations of the Malheur Lakes SMU. In addition, threats not significant to these redband trout populations but important to fisheries management in general are discussed to provide background information for management actions. Population specific information is provided in section 4.5.

### 4.4.1 Significantly Ranked Threats

<u>Land Management</u>

Land use practices have dramatically affected the landscape in Oregon's high desert with lasting impacts on stream habitat and native fish populations. Timber harvest, agricultural activities and grazing operations are the primary land uses in Harney County (HCWC 2000, 2001). These have altered the structure and function of stream ecosystems, impacted watershed processes, and contribute significantly to factors limiting redband trout populations. In a number of instances historical land use activities are no longer common practice, however current management is neither sufficient to ameliorate the factors caused by past practices nor restoration activities have not been adequately implemented. Current land use practices, while improved significantly in recent decades, may still impact aquatic habitats and watershed health.

Land management generates a number of key concerns for redband trout, contributing significantly to many of the limiting factors identified by the expert panel. The significant impacts common to most populations are as follows.

Extensive timber harvest, livestock grazing, and agricultural activities notably interrupt watershed processes, the consequences of which have significant and direct impacts to redband trout and their habitat. The removal of vegetation in the uplands and within the riparian areas, in combination with soil compaction associated with trampling and mechanical harvesting, increases the degree of overland flow during precipitation events. Instead of infiltrating into the soil to replenish the water table, water runs off into the stream channel increasing peak flow volume and velocity. Typically riparian vegetation slows in-stream water velocity and minimizes erosion through stream bank roughness, complexity and vegetative root strength. In systems where riparian vegetation is degraded or removed stream banks quickly erode, collapse, and widen often causing down cutting and entrenchment. A lower water table and the incision of the stream channel disconnect the stream from its floodplain, in which case, side channels and off channel habitat that once provided refuge from floods, hiding cover, and productive habitat for juvenile rearing are no longer accessible. The lower water table and reduced outflow from springs and seeps diminish the potential for slow release of water throughout the year creating lower flows in the late summer and fall.

Unstable and eroding stream banks can contribute a significant proportion of the fine sediment load in a system. The high rate of erosion associated with land use activities increases the sedimentation of the stream channel, filling interstitial spaces invertebrates and small fish use for cover, embedding gravels adult trout use for spawning, and filling deeper pools fish use for rearing. The sedimentation of stream gravels has been linked to decreased fry emergence, juvenile densities, and winter carrying capacity and increased predation rates. The lower frequency of deep pools and the associated lack of complexity do not provide the structure the stream channel needs to retain gravels used for spawning and invertebrate production.

The removal and degradation of riparian vegetation and other sources of streamside shading (i.e. timber) exposes the water's surface to solar radiation ultimately contributing to elevated in-stream water temperatures. Similarly, degraded riparian conditions can result in wider stream channels that further increase the exposure to solar input. The resultant warmer in-stream water temperatures and lower levels of dissolved oxygen, particularly in the summer, can directly impact redband trout. At temperatures exceeding the preferred range, trout will experience physiological stress and reduced growth. Low flows exacerbate the situation where lower water volumes heat up at faster rates.

Timber and forestry activities have generated extensive networks of forest roads. Many of these roads are improperly located, constructed or maintained. Heavily roaded areas lead to an increase in sedimentation and decreased stream flow through an interruption of watershed processes. In addition improper culvert placement at stream crossings can reduce or eliminate upstream fish passage, preventing access to spawning habitat and intra-population mixing.

Diking, dredging, and draining of wetlands, in conjunction with the removal of beaver from the landscape (HCWC 2001) have reduced, if not eliminated, wetland habitats historically present in moderate to low gradient reaches of Malheur Lakes basin. These activities alter ecosystem dynamics and effectively eliminate rich and productive habitats ideal for rearing large migratory fish.

Fire suppression and long term changes in air temperature and precipitation have resulted in an increase in woodland juniper abundance and distribution. Encroachment and the eventual dominance of juniper can have significant impact on soil resources, plant community structure and composition, water and nutrient cycles, wildlife habitat and biodiversity (Miller et al 2005). Relevant to redband trout and in-stream habitat condition, juniper encroachment can impact the watershed's ability to capture water (Barrett 2007). Precipitation interception, increased transpiration rates and diminished soil infiltration rates of juniper woodlands reduce soil moisture and the volume of water available to the water table (Barrett 2007, Miller et al 2005). However, controlled watershed scale studies that demonstrate a direct link between juniper encroachment and groundwater flow do not exist, though anecdotal evidence suggests a direct connection. Streams, springs, and meadows have dried due to juniper encroachment or flow again after the removal (Miller et al 2005). The relationship between western juniper and subsurface flow is likely site specific, determined by topography, soils, geology and climate (Miller et al. 2005).

Juniper encroachment also results in the die-off of native shrubs, grasses and forbs in the understory, often to the detriment of healthy riparian areas. This loss of protective plant cover causes an increase of overland flow and soil erosion during precipitation events (Miller et al

2005). Systems where juniper encroachment has outcompeted native riparian vegetation suffer from chronic sediment delivery, unstable banks, and a lack of streamside shade.

The expert panel identified juniper encroachment as playing an important role in declining stream flow and chronic in-stream sediment delivery in many of the watersheds in the Malheur Lakes basin. The Planning Team agrees extensive juniper encroachment can significantly impact physical in-stream habitat quality and the treatment of juniper can result in greater bank stability, sediment capture, streamside shading and nutrient input. While it is clear that juniper removal is beneficial for fuel reduction, aspen conservation, rangeland & forest health and wildlife habitat, significant uncertainty exists as to whether it will directly and significantly enhance water quantity and viability of redband trout. Therefore juniper encroachment is listed in this plan as a threat impacting only physical habitat quality and not a key or secondary threat to water quantity.

Non-point source pollution is caused by runoff and snowmelt moving over and through the ground. As the runoff moves, it picks up and carries away natural and human made pollutants ultimately depositing them into lakes, streams, rivers and wetlands ultimately degrading water quality. These pollutants might include fertilizer, herbicides, pesticides, oil & grease, sediment, and nutrients from livestock or faulty septic systems.

<u>Water Management</u>

Water management in the Malheur Lakes basin is very closely tied to land management activities where the primary water use is for agricultural purposes. Hydropower and flood control operations do not exist in the basin. Threats associated with water management are due to water diversion dams, water withdrawal and irrigation return, channelization of stream corridors, and the over appropriation of water.

Dams and diversions associated with water withdrawal systems can impede access for redband trout to critical habitats. Many diversion dams are constructed without any means of fish passage. Migrating fish encountering these barriers may be prohibited from accessing upstream spawning grounds or prevented from moving further downstream to large productive rearing habitats. Both situations result in a decrease of overall fitness and productivity. While some diversion dams may provide upstream passage, they may still impede or delay movement during migrations which can ultimately affect spawning success (Anderson 2009). Similarly many irrigation diversions are unscreened, often entraining fish into the irrigation system. In many instances these fish become trapped in the irrigation complex and have no means to return to the natural stream network.

Stream channels have been altered to efficiently transfer water across the landscape. This often involves channelizing or straightening the waterway with dikes and revetments or diverting water from the natural stream course into an artificial canal. In most cases, the physical habitat quality is highly degraded where in-stream habitat complexity is grossly simplified; hampering natural stream processes, eliminating holding and feeding locations and exposing fish to high velocities and predators.

In many basins water is over appropriated where the volume of surface water is not adequate to meet all of the expected demands or water rights (HCWC 2001). This results in decreased in-stream flows, potentially drying portions of the stream in the late summer and fall months.

Water management at dams and small reservoirs can change a streams natural hydrograph. Typically, high flows in Oregon's high desert occur during spring snow melt and occasional summer rainstorms. Dams and water withdrawal moderate these peak flows, potentially impacting juvenile fish that out-migrate during spring freshets or adult fish for which river discharge serves as a cue to initiate a spawning migration (Anderson 2009). Furthermore, irrigation activities return water to the streams at times not naturally experiencing high flows.

<u>Introduced Species</u>

The Technical Team identified direct and indirect interactions with non-native species as key and secondary threats to a number of redband trout populations in the basin. Introduced fish species have impacted redband trout and their habitats. Common carp, brook trout and smallmouth bass prey on redband trout, compete for resources, and alter important habitats.

Common Carp (*Cyprinus carpio*) have been present in Silvies River since the 1920's and have spread. They overlap redband trout populations in the large low gradient rivers and lakes of the Malheur Lakes Basin. Carp root for macroinvertebrate prey in the substrate dislodging vegetation and suspending sediments. The resulting increase in turbidity and decrease in macrophytes (aquatic plants) is detrimental to native fish and waterfowl alike. High turbidity levels reduce the ability of visual predators, such as trout, to find food. Subsurface sunlight needed for plant growth is reduced or eliminated and photosynthetic plant production and oxygen levels decrease **(**USFWS 2012 Appendix E). Over time, carp can change the physical environment of an aquatic system to a point where only a few species of fish, invertebrates and plants can survive in low numbers. Malheur Lake, for example, has transitioned from a macrophyte-dominated, clear-water system to a phytoplankton-dominated, turbid water state that is sub-optimal for redband trout (CCP 2012).

Brook trout, introduced to Malheur Lakes basin in 1926, are sympatric with redband trout in the upper tributaries of the Silvies River System. While brook and redband trout can coexist, there is evidence that in the presence of brook trout redband trout are at lower density and of smaller size (Miller et al. 2014) having a negative impact on abundance and productivity.

Non-native warmwater fish species, such as smallmouth bass, bullheads and white crappie, are common in the larger rivers and terminal lakes in the basin. These species negatively impact redband trout through predation but also indirectly through competition for food and space, increasing mortality and decreasing abundance and productivity.

### 4.4.2 Other non-ranked threats

A number of threats were identified by the technical committee but were not ranked as a key or secondary threat to the viability of redband trout. However, the expert panel believes they are worth mentioning in this plan either because they are significant to the management of the species (i.e. harvest and hatcheries) or because the degree of the threat is undocumented and unknown but an important land management issue that seemingly could have relevance to redband trout populations, particularly to the smallest isolated populations.

Harvest Management

Redband trout can be caught in recreational fisheries throughout the Malheur Lakes basin. These fisheries can influence population viability by causing direct and indirect mortality. Direct mortality occurs through the actual harvest of a fish. Incidental mortality occurs by mortality to fish caught then released alive, hooked by fishing gear but not landed, or harvested incidentally to the target species. Harvest impacts directly affect adult abundance, and therefore the number of spawners. This can have significant direct implications on all viable population parameters – abundance and productivity through a decrease in effective population size, and diversity and spatial structure through age, size and timing selection. The magnitude of these effects can be effectively managed through regulations associated with fishery dates, gear types allowed, size restrictions, and others.

Harvest was not identified as a significant threat for any redband trout population in the Malheur Lakes SMU. Based on angler reports the expert panel believes angling pressure in most populations is minimal. However, harvest rates and the impacts of these fisheries to redband trout populations have not been examined using empirical data. A number of the populations are fished at unknown rates, particularly those in small isolated streams mostly located on private property. The Blitzen River receives the most fishing pressure as a renowned sport fishery for trophy-size trout. Current angling regulations for trout are two fish over eight inches per day using only artificial flies and lures from late May to October 21 (closed to retention the rest of the year). Exceptions are described in Table 4-5.

**Table 4-5. Exceptions to the current angling regulations of two 8" trout per day with artificial flies and lures in the Malheur Lakes SMU.** ** - Note: Since harvest was not identified as a significant limiting factor, regulation changes consistent with the conservation of all populations may be proposed in the future for management purposes.*

| Waterbody | Regulation |
|---|---|
| **Blitzen River -** downstream of Bridge Creek | Open from Sod House Dam to the mouth during August and September |
| **Krumbo Creek** – below reservoir | Closed |
| **Blitzen River** – above Bridge Creek and Tributaries including the East Canal | Catch and release only, artificial flies and lures |
| **Little Blitzen River** | Catch and release only, artificial flies and lures |
| **Kiger Creek** and tributaries<br>**Krumbo Reservoir** and tributaries<br>**Rattlesnake Creek** and tributaries<br>**Riddle Creek** and tributaries<br>**McCoy Creek** and tributaries<br>**Little Fish Creek**<br>**Little Indian Creek**<br>**Tributaries of the Blitzen River except the L. Blitzen**<br>**Silvies River** and tributaries<br>**Silver Creek** and tributaries | 5 trout per day, use of bait allowed* |

<u>Hatchery Management -Stocking of Hatchery Raised Trout</u>

While intended to provide recreational fishing opportunities in the basin, hatchery programs pose both genetic and ecological risks to wild populations. Genetic risks occur when hatchery and wild fish interbreed and result in reduced fitness of the wild population. Ecological risks occur when the presence of hatchery fish affects how wild fish interact with their environment or with other species and may affect whole species assemblages (Kostow 2009). Examples of ecological risk include increased competition for food and space or higher predation rates. Releases of hatchery raised fish also increase the risk of disease outbreaks and can alter life history traits of the native population. The stocking of hatchery origin rainbow trout pose the greatest risk for native redband trout given the two sub-species can hybridize, compromising the genetic integrity of native fish.

Extensive planting of coastal rainbow stock began in the 1920s throughout the Malheur Lakes Basin, however the evidence of introgression of wild redband trout with hatchery rainbow trout has not been overwhelming. A few genetic studies have occurred in streams of the Blitzen and Silvies populations. In the Blitzen River basin strong evidence of introgression does not appear in genetic studies on Bridge and Mud creeks (Currens et al. 1997). The contribution of hatchery rainbow trout was found to be approximately 0.6% in McCoy Creek and 4.9% in Kiger Creek (Phelps et al. 1996). In the Silvies River basin moderate levels of introgression with hatchery fish was noted in studies in Emigrant and Nicol creeks (Williams and Shiozawa 1992) and on the mainstem Silvies near historical stocking sites (Hosford and Prybil 1991). Thus evidence of high levels of introgression is absent in places where genetics have been examined. Despite extensive stocking efforts, coastal-origin hatchery fish have not replaced native redband trout in the northern Great Basin. The level of introgression between native redband trout and hatchery origin fish varied among populations within the SMU, and among individuals within populations (Dehaan et al. 2015). Two hypotheses exist for explaining the observed introgression: 1) The harsh environmental conditions of the high desert, including high temperatures and oxygen depletion, select for genotypes adapted to unstable environments - which probably explains why arid-region redband trout have successfully resisted hybridization (Behnke 1992); and 2) hatchery rainbow trout stocked by ODFW were and are fall-spawning fish. However, given the extensive stocking history and the degree of introgression observed range-wide (WNTI 2012, Mulhfeld et al. In Press), further and more thorough investigation into potential introgression is extremely relevant and necessary.

Hatchery origin rainbow trout are not currently stocked in moving waters of the Malheur Lakes Basin. The stocking program in streams and rivers was ceased in 1973 in Silver Creek, 1992 in the Blitzen basin and 1993 in the Silvies basin. Standing water bodies currently planted with triploid (sterile) coastal rainbow trout are Krumbo Reservoir and Fish Lake in the Blitzen River basin; Yellowjacket Lake and the Burns Pond in the Silvies River Basin; and Delintment Lake, Moon Reservoir and Chickahominy Reservoir in the Silver Creek basin. It is believed that fish are unable to escape these waterbodies and therefore threats associated with competition, predation, disease and introgression in redband trout populations do not exist.

<u>Introduced Species – Cheatgrass and Medusahead Rye</u>

Cheatgrass (*Bromus tectorum*) and medusahead rye (*Taeniatherum caput-medusae*) are highly invasive non-native annual grasses introduced near the turn of the 20th century through the import of grain and livestock from Europe and Asia. Their greatest threat to the sagebrush – steppe ecosystem is of altered native plant communities and system response to fire particularly post-fire flooding and erosion. Both species out compete native perennial grasses for moisture, nutrients, and space through prolific seed production, fall and early spring germination (grows taller before native grasses), thick and shallow root systems, and extremely high plant densities. Their overwhelming dominance alters ecosystem attributes by reducing soil moisture, decreasing native plant diversity, and altering wildlife habitats. The short early summer growth period and dense litter cover leaves watersheds extremely vulnerable to fire, increasing the chance, frequency and spread of fire over the long term. Climate change paired with the threat of cheatgrass invasion, particularly on disturbed soils, is a real cause for concern related to fire and post-fire impacts (Pellant 1996). Even with these system-wide effects the invasion of non-native grasses and weeds have not demonstrated a direct or strong indirect impact on stream habitats and redband trout. While impacts of cheatgrass and medusahead rye are of significant concern to watershed health in the Malheur Lakes basin, the Planning Team chose not to rank their invasion as a key threat to redband trout given the lack of direct and immediate effects on VSP parameters of redband trout populations.

Land management – Private land access

Most populations exist to some degree on lands to which agency access has not been provided by the landowner. For many of these populations, public lands or access to private property is great enough that the population can be monitored and evaluated with an acceptable degree of certainty. However, in a handful of populations, lack of access precludes a reliable evaluation of the population or limiting factors. The technical committee feels these populations are at high risk simply due to a lack of information regarding their status, trends, and threats. Without reliable information, management actions necessary to prevent population loss or extinction are not identifiable.

## 4.5 Effects of Climate Change

Alteration of aquatic habitats due to climate change is a real threat to the persistence of redband trout in the Great Basin. Climatologists and modelers continue to refine their estimates of the potential effects that could be expected into the future. The potential impacts of future climate change to the Malheur Lakes redband trout SMU are described in Appendix 4. Estimated warmer and dryer summers, along with higher flows in the winter, as a result of further climate change will only exacerbate the current limiting factors associated with degraded water quality, water quantity and physical habitat. For this reason, this plan does not separate out climate change as a stand-alone threat. Actions to address this threat, other than actions to address the limiting factors identified for water quality, water quantity and physical habitat, are beyond the purview of this plan. Because the speed and severity of future climate change is not completely understood or agreed upon, it is difficult to determine the quantity of actions that will be needed to offset the impact. Adaptive management will allow adjustments to be made in this plan to better address climate change in the future.

## 4.6 Threats and Associated Limiting Factors for Malheur Lakes Redband Trout Populations

The key and secondary limiting factors and threats that contribute to the current status of redband trout populations in the Malheur Lakes are shown in Tables 4.7 –4.19 for each population below. The codes used in all tables are described in Table 4-6. Population specific details on the limiting factors and threats are provided in Appendix 3.

**Table 4-6. Codes used for summarizing limiting factors and threats in Tables 4.7 – 4.15 and subsections below.**

| Code | Limiting Factor | Threat |
|---|---|---|
| 1 | Water Quantity: Decreased Stream flow | b. Water Withdrawal |
| | | c. Agriculture and Irrigation Activities |
| | | e. Grazing, Timber, & Riparian Management Practices |
| 1 | Water Quantity: Altered Hydrograph | h. Irrigation Practices |
| | | j. Reservoir Operations |
| 2 | Water Quality: Temperature | a. Reservoir Conditions |
| | | b. Irrigation Practices |
| | | c. Water Withdrawal |
| | | e. Grazing, Timber, & Riparian Management Practices |
| 2 | Water Quality: Chemical & Turbidity | g. Non-Point Source Pollution |
| | | j. Non-native Species: Carp, Bullhead |
| 3 | Predation | a. Non-native Species: Smallmouth Bass, Brook Trout |
| 4 | Competition | a. Non-native Species: Carp, Largemouth Bass, Brook Trout |
| 6 | Physical Habitat: Degradation | b. Channelization |
| | | c. Water Withdrawal |
| | | f. Grazing, Timber, & Riparian Management Practices |
| | | g. Recreation |
| | | h. Juniper Encroachment |
| | | l. Road Construction - Channel Confinement |
| 6 | Physical Habitat: Siltation | d. Grazing, Timber, & Riparian Management Practices |
| | | e. Forest Roads |
| 7 | Habitat Access | a. Dams and Diversions |
| | | b. Culvert Crossings |
| 8 | Other Factors | b. No Agency Access |

### 4.6.1 Factors and threats limiting viability of Silver Creek redband trout

**Table 4-7. Key and secondary limiting factors of the Silver Creek redband trout population. Bolded and shaded codes are key concerns and non-bolded/shaded codes are secondary concerns.**

| Threat | Headwater / Tributary | | | | | Large River / Lake | |
|---|---|---|---|---|---|---|---|
| | egg | juvenile | resident sub-adult | resident adult | spawner | migratory sub-adult | migratory adult |
| Water Management | | | | | | **1b, 2c, 6c, 7a** | |
| Land Management | **6d, 6e** | | | | **6d, 6e** | **1c, 2e, 6d, 6f** | |
| | **1e, 2e, 6f, 7b** | | | | | | |
| Introduced Species | | | | | | 2j, 4a | |
| Hatchery | | | | | | | |
| Harvest | | | | | | | |

The greatest threats to redband trout in the Silver Creek basin were generated from intense land-use beginning in the late 1800s. Over one hundred years of timber harvest, beaver trapping, and livestock grazing have impaired historical watershed processes and significantly altered the condition and function of in-stream habitats. Although timber, agriculture, and grazing practices are vastly improved over those employed historically (pre 1980's) stream habitats in many locations are still being impacted and others are slow to recover leaving redband trout vulnerable to elements of risk.

### 4.6.2 Factors and threats limiting viability of Silvies River redband trout

**Table 4-8. Key and secondary limiting factors of the Silvies River redband trout population. Bolded and shaded codes are key concerns and non-bolded/shaded codes are secondary concerns.**

| Threat | Headwater / Tributary | | | | | Large River / Lake | |
|---|---|---|---|---|---|---|---|
| | egg | juvenile | resident sub-adult | resident adult | spawner | migratory sub-adult | migratory adult |
| Water Management | | | | | | **1b, 2b, 2c, 6b, 6c, 7a** | |
| Land Management | **6d, 6e** | | | | **6d, 6e** | **1e, 2e, 6f** | |
| | 1e, 2e, 6f, 7b | | | | | | |
| Introduced Species | | | | | | **2j,** 3a, **4a** | |
| Hatchery | | | | | | | |
| Harvest | | | | | | | |

The most significant threats to redband trout viability occur in the mainstem of the Silvies River. From Seneca to Malheur Lake the Silvies River is impaired by poor water quality and low flow issues, degraded and simplified habitats and the presence of non-native fish that compete with and prey upon redband trout. The Silvies River is an important migratory corridor and rearing habitat for migratory redband trout. The degraded conditions in the mainstem hinder trout use particularly in the summer months, potentially fragmenting the population and isolating fish residing in the tributaries. Although many of the tributary streams suffer from poor quality habitat, the cumulative limiting factors in the mainstem river and low elevation valley bottom habitats pose the greatest threat to redband trout.

### 4.6.3 Factors and threats limiting viability of Poison Creek redband trout

**Table 4-9. Key and secondary limiting factors of the Poison Creek redband trout population. Bolded and shaded codes are key concerns and non-bolded/shaded codes are secondary concerns.**

| Threat | Headwaters / Tributaries | | | | |
|---|---|---|---|---|---|
| | egg | juvenile | resident sub-adult | resident adult | spawner |
| Water Management | | | | | |
| Land Management | 2g, 6d, **6e**, **6f**, 8b | | | | |
| Introduced Species | | | | | |
| Hatchery | | | | | |
| Harvest | | | | | |

The most significant limiting factor to Poison Creek redband trout is habitat condition. State Highway 395 runs parallel to the stream channel along the lowest reach of Divine Canyon Creek. Channel constriction and contaminated highway run-off impact the physical in-stream habitat and water quality. Water quantity is naturally low; however, stream temperatures are very cold due to headwater springs.

### 4.6.4 Factors and threats limiting viability of Prater Creek redband trout

**Table 4-10. Key and secondary limiting factors of the Poison Creek redband trout population. Bolded and shaded codes are key concerns and non-bolded/shaded codes are secondary concerns.**

| Threat | Headwater / Tributary | | | | |
|---|---|---|---|---|---|
| | egg | juvenile | resident sub-adult | resident adult | spawner |
| Water Management | | | | | |
| Land Management | **1e,** 8b | | | | |
| Introduced Species | | | | | |
| Hatchery | | | | | |
| Harvest | | | | | |

Data and ancillary information pertinent to limiting factors in Prater Creek is lacking. Based on professional judgment the technical committee believes water quantity is the most significant threat to redband trout in Prater Creek. Flows during low water years are intermittent and the upper reaches are dry during summer months. While many of the factors presumed to be contributing to low flow are not anthropogenic (small basin size, naturally porous soils, topology) current and historical land-use practices exacerbate the issue. In addition, access to private property in a significant portion of the distribution is prohibited, limiting our ability to assess population status and limiting factors.

### 4.6.5 Factors and threats limiting viability of Coffeepot Creek redband trout

**Table 4-11. Key and secondary limiting factors of the Coffeepot Creek redband trout population. Bolded and shaded codes are key concerns and non-bolded/shaded codes are secondary concerns.**

<table>
<tr><th rowspan="2">Threat</th><th colspan="5">Headwater / Tributary</th></tr>
<tr><th>egg</th><th>juvenile</th><th>sub-adult</th><th>adult</th><th>spawner</th></tr>
<tr><td rowspan="2">Water Management</td><td></td><td></td><td>7a</td><td>7a</td><td></td></tr>
<tr><td colspan="5">1b, 2b, 2c</td></tr>
<tr><td>Land Management</td><td colspan="5">1e, 2e, 6f, 8b</td></tr>
<tr><td>Introduced Species</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Hatchery</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Harvest</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Limiting factors to redband trout viability in Coffeepot Creek are associated with water and habitat quality. Current and historical land-use practices have negatively impacted habitat structure and natural stream processes. In addition, the technical committee identified threats associated with water management that impact habitat in the lowest, possibly intermittent, reaches thereby limiting the potential for trout to occupy this portion of the watershed.

### 4.6.6 Factors and threats limiting viability of Rattlesnake Creek redband trout

**Table 4-12. Key and secondary limiting factors of the Rattlesnake Creek redband trout population. Bolded and shaded codes are key concerns and non-bolded/shaded codes are secondary concerns.**

<table>
<tr><th rowspan="2">Threat</th><th colspan="5">Headwater / Tributary</th></tr>
<tr><th>egg</th><th>juvenile</th><th>sub-adult</th><th>adult</th><th>spawner</th></tr>
<tr><td rowspan="2">Water Management</td><td></td><td></td><td>7a</td><td>7a</td><td></td></tr>
<tr><td colspan="5">1b, 2c</td></tr>
<tr><td rowspan="2">Land Management</td><td colspan="2">6d, 6e</td><td></td><td></td><td>6d, 6e</td></tr>
<tr><td colspan="5">1e, 2e, 6f, 6l</td></tr>
<tr><td>Introduced Species</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Hatchery</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Harvest</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Threats to Rattlesnake Creek redband trout are primarily associated with decades of intensive land management (HCWC 2001). Historical grazing and timber harvest practices have caused basin-wide degradation of watershed processes culminating in sub-optimal conditions for trout. While current practices are vastly improved over those implemented in the past, current land and water use practices are either not adequate to restore habitat or hinder recovery in the headwater and low elevation reaches.

### 4.6.7 Factors and threats limiting viability of Cow Creek redband trout

**Table 4-13. Key and secondary limiting factors of the Cow Creek redband trout population. Bolded and shaded codes are key concerns and non-bolded/shaded codes are secondary concerns.**

| Threat | Headwater / Tributary | | | | |
|---|---|---|---|---|---|
| | egg | juvenile | sub-adult | adult | spawner |
| Water Management | | | 7a | | |
| | **1b** | | | | |
| Land Management | 6d, 6e | | | | 6d, 6e |
| | **1e**, **2e**, **6f** | | | | |
| Introduced Species | | | | | |
| Hatchery | | | | | |
| Harvest | | | | | |

Factors affecting the viability of Cow Creek redband trout are primarily related to water quantity and physical habitat quality. Stream flow is intermittent during low water years where the upper and middle reaches are periodically dry (ODFW, NFI unpublished data). Excessive sedimentation, trampled stream banks, and deteriorated riparian areas have degraded physical habitat quality throughout the basin.

### 4.6.8 Factors and threats limiting viability of Riddle Creek redband trout

**Table 4-14. Key and secondary limiting factors of the Riddle Creek redband trout population. Bolded and shaded codes are key concerns and non-bolded/shaded codes are secondary concerns.**

| Threat | Headwater / Tributary | | | | | Large River / Lake | |
|---|---|---|---|---|---|---|---|
| | egg | juvenile | resident sub-adult | resident adult | spawner | migratory sub-adult | migratory adult |
| Water Management | | | | | | **1b**, **2c**, 6b, 6c, **7a** | |
| Land Management | **2e**, **6f**, 6h, 8b | | | | | **2e** | |
| Introduced Species | | | | | | | |
| Hatchery | | | | | | | |
| Harvest | | | | | | | |

Threats limiting redband trout in the Riddle Creek sub-basin primarily occur in the low elevation reaches, downstream of Smyth Reservoir. Conditions here likely prevent redband trout from rearing in these reaches, limiting the expression of the migratory life history. Habitat quality in Smyth Creek below the reservoir and Riddle Creek between Paul Creek and Dry Lake Reservoir is severely degraded (WNTI 2012). Irrigation operations in these reaches divert flow from the natural channel into a series of human-made canals and artificial channels, leaving the natural stream course dry (Based on Technical Team input). Impassable barriers at Smyth Reservoir and Dry Lake Reservoir prevent fish rearing in these habitats from returning upstream to spawn, ultimately decreasing productivity and life history diversity.

In addition, habitat conditions in the headwater streams potentially impact redband trout. In-stream habitat in Upper Smyth, Riddle and Coyote creeks was rated as in fair condition (WNTI 2012), and Coyote and Paul creeks experience high stream temperatures year around and during the summer months, respectively (ODEQ 2010).

#### 4.6.9 Factors and threats limiting viability of Blitzen redband trout

**Table 4-15. Key and secondary limiting factors of the Blitzen River redband trout population. Bolded and shaded codes are key concerns and non-bolded/shaded codes are secondary concerns.**

| Threat | Headwater / Tributary | | | | | Large River / Lake | |
|---|---|---|---|---|---|---|---|
| | egg | juvenile | resident sub-adult | resident adult | spawner | migratory sub-adult | migratory adult |
| Water Management | | | | | | 1b, 1h, 2b, **2c, 6b, 6c, 7a** | |
| Land Management | **6f,** 6h | | | | | **2e,** 2g, **6f** | |
| Introduced Species | | | | | | 2j, 4a | |
| Hatchery | | | | | | | |
| Harvest | | | | | | | |

The Blitzen River is considered to be one of the crown jewels of redband trout habitat in Oregon's high desert. The headwater streams in the Steens Mountain are thought to be close to pristine and capable of supporting a healthy population of redband trout. This is fairly accurate when compared to other high desert redband trout populations; however the Blitzen River Basin is not without conditions hampering abundance, productivity, spatial structure and diversity of the redband trout population.

Settled in the late 1800's, the Blitzen Valley quickly became the center for sheep and cattle grazing operations in the region. The following decades of heavy grazing and associated activities impacted most of the streams throughout the basin. Recent grazing restrictions have allowed many riparian habitats to recover. The Blitzen River above Fish Creek is now the nation's first redband trout reserve where land management activities promote environmental education, fish and wildlife recreation, and scientific research (BLM 2005).

Currently, threats to redband trout VSP parameters have the greatest impact in the lower elevation streams including the lower Blitzen River through the Malheur National Wildlife

Refuge and the lower reaches of Kiger and McCoy drainages. Cattle grazing and irrigated hay production prompted the development of a system of dikes, canals, drains and water control structures in the lower Blitzen Valley in the late 1800s. The system was used to control the movement of water across the landscape and to drain wetlands for grazing and farming activities (Burnside 2008). Today, more than 900 water control structures exist in the Blitzen Valley as part of the intensive delivery system used by the Malheur National Wildlife Refuge to manage ponds, meadows, and wetlands for migratory birds and wildlife (USFWS 2012). These threats, channel straightening, dams and diversions and agricultural practices, also impact fish and their habitat in the lower portion of McCoy and Kiger Creeks.

# CHAPTER 5

# MANAGEMENT STRATEGIES AND ACTIONS

## 5.1 Introduction

In order to achieve the desired status identified in this plan, it will be necessary to address those elements that appear to affect the status of the population – the factors that are limiting the population's status. Strategies that focus effort on the factors most limiting a population will be the most effective and efficient approach to achieving the intended goal. The objectives of this chapter are to identify the limiting factors to be focused on for each redband trout population, to identify the strategy/strategies to address the limiting factors, and to describe actions that should be taken to implement the strategy/strategies.

## 5.2 Management Strategies

Table 5-1 provides a list of all of the management strategies identified to address limiting factors in all populations of the Malheur Lakes redband trout SMU. The table also indicates which strategies were identified for each population. The sections below provide more detail on the strategies by individual population and then describes the actions needed to address each strategy.

**Table 5-1.** Summary of management strategies for each redband population.

| | Population | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Strategy** | **Silver** | **Silvies** | **Poison** | **Prater** | **Coffeepot** | **Rattlesnake** | **Cow** | **Riddle** | **Blitzen** |
| Restore and maintain water quality. | X | X | X | | X | | X | X | X |
| Restore and maintain water quantity. | X | X | X | X | | | X | X | X |
| Restore degraded upland processes and maintain natural upland processes. | X | X | X | | | | | X | X |
| Restore passage and connectivity to habitats blocked or impaired by artificial barriers. | X | X | X | | | | | X | X |
| Restore and maintain channel structure and complexity. | X | X | X | | | X | X | X | X |
| Restore riparian condition and large woody debris (LWD) recruitment, and maintain unimpaired conditions. | X | X | X | | X | X | X | X | X |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Reduce the impact and prevent the introduction of introduced species. | | X | X | | | | | | |
| Restore and maintain unimpaired floodplain connectivity and function. | | | | | X | X | | | |
| Assess the status of populations and habitats with limited information. | | | | X | X | | | | |

Silver Creek

The current status assessment for the Silver Creek redband trout population found that spatial structure was the population's highest risk of the four parameters assessed (high risk), followed by diversity (moderate risk) and productivity (low risk).

The Technical Team identified limiting factors related to water quantity, water quality, habitat degradation and habitat access as key concerns. Reduced habitat access as a limiting factor is confirmed by the poor spatial structure and diversity scores from the assessment. The degraded condition of the habitat and water quantity/quality likely contributed to the poor spatial structure and diversity scores, as well as the lower productivity score.

Based on the findings of both the assessment and Technical Team's limiting factors, the following strategies should be pursued to improve the status of the Silver creek population:

- *Restore and maintain water quality sufficient to support the needs of redband trout.*
- *Restore and maintain water quantity sufficient to support the needs of redband trout.*
- *Restore degraded upland processes to minimize unnatural rates of erosion and runoff, and maintain natural upland processes.*
- *Restore passage and connectivity to habitats blocked or impaired by artificial barriers, and maintain unimpaired passage and connectivity.*
- *Restore channel structure and complexity, and maintain unimpaired structure and complexity.*
- *Restore riparian condition and LWD recruitment, and maintain unimpaired conditions.*

Silvies River

The current status assessment for the Silvies River redband trout population found that spatial structure was the population's highest risk of the four parameters assessed (high risk), followed by diversity (low risk) and productivity (low risk).

The Technical Team identified limiting factors related to water quantity, water quality, habitat degradation, habitat access, and introduced species as key concerns. Reduced habitat access and introduced species as threats are confirmed by the poor spatial structure and diversity scores from the assessment. The degraded condition of the habitat and water quantity/quality likely contributed to the poor spatial structure score, as well as the lower diversity and productivity score.

Based on the findings of both the assessment and Technical Team's limiting factors, the following strategies should be pursued to improve the status of the Silvies River population:

- *Restore and maintain water quality sufficient to support the needs of redband trout.*
- *Restore and maintain water quantity sufficient to support the needs of redband trout.*
- *Restore degraded upland processes to minimize unnatural rates of erosion and runoff, and maintain natural upland processes.*
- *Restore passage and connectivity to habitats blocked or impaired by artificial barriers, and maintain unimpaired passage and connectivity (consistent with introduced species strategy below).*
- *Restore channel structure and complexity, and maintain unimpaired structure and complexity.*
- *Restore riparian condition and LWD recruitment, and maintain unimpaired conditions.*
- *Reduce the impact of introduced species on redband trout populations and prevent the introduction of new non-native species.*

<u>Poison Creek</u>
The current status assessment for the Poison Creek redband trout population found that spatial structure was the population's highest risk of the four parameters assessed (high risk), followed by diversity (moderate risk) and productivity (low risk).

The Technical Team identified limiting factors related to water quantity, water quality, habitat degradation and habitat access as key concerns. Reduced habitat access as a threat is confirmed by the poor spatial structure and diversity scores from the assessment. The degraded condition of the habitat and water quantity/quality likely contributed to the poor spatial structure and diversity scores, as well as the lower productivity score.

Based on the findings of both the assessment and Technical Team's limiting factors, the following strategies should be pursued to improve the status of the Poison Creek population:

- *Restore and maintain water quality sufficient to support the needs of redband trout.*
- *Restore and maintain water quantity sufficient to support the needs of redband trout.*
- *Restore degraded upland processes to minimize unnatural rates of erosion and runoff, and maintain natural upland processes.*
- *Restore passage and connectivity to habitats blocked or impaired by artificial barriers, and maintain unimpaired passage and connectivity.*
- *Restore channel structure and complexity, and maintain unimpaired structure and complexity.*
- *Restore riparian condition and LWD recruitment, and maintain unimpaired conditions.*

- *Reduce the impact of introduced species on redband trout populations and prevent the introduction of new non-native species.*

<u>Prater Creek</u>
The current status assessment for the Prater Creek redband trout population scored all four parameters at high risk. There was very little data from which to assess the status of the population's abundance, productivity and distribution. This was due to an inability to sample the fish on private property. As a result, the status assessment does not provide much insight into what may be limiting the population.

The lack of access also impacted the ability of the Technical Team to identify limiting factors. The Team believed that the greatest limiting factor was water quantity. The lack of access to assess the population was also identified as a risk to understanding and improving the population's status.

Based on the findings of the Technical Team, the following strategies should be pursued to improve the status of the Prater Creek population:

- *Restore and maintain water quantity sufficient to support the needs of redband trout.*
- *Assess the status of the population and its habitats.*

<u>Coffeepot Creek</u>
The current status assessment for the Coffeepot Creek redband trout population was primarily based on best professional judgment. There was very little data from which to assess the status of the population's abundance, productivity and distribution. This was due to an inability to sample the fish on private property. As a result, the status assessment does not provide much insight into what may be limiting the population.

The Technical Team identified water quality and degraded habitat as key limiting factors. The lack of access to assess the population was also identified as a risk to understanding and improving the population's status.

Based on the findings of the Technical Team, the following strategies should be pursued to improve the status of the Coffeepot Creek population:

- *Restore and maintain water quality sufficient to support the needs of redband trout.*
- *Restore riparian condition and LWD recruitment, and maintain unimpaired conditions.*
- *Restore floodplain connectivity and function and maintain unimpaired floodplain connectivity and function.*
- *Assess the status of the population and its habitats.*

<u>Rattlesnake Creek</u>
The current status assessment for the Rattlesnake Creek redband trout population found that spatial structure was the population's highest risk of the four parameters assessed (high risk), followed by diversity (moderate risk) and productivity (low risk).

The Technical Team only identified habitat degradation as a key limiting factor. The degraded condition of the habitat contributed to the poor spatial structure and diversity scores, as well as the lower productivity score.

Based on the findings of both the assessment and Technical Team's limiting factors, the following strategies should be pursued to improve the status of the Rattlesnake creek population:

- *Restore channel structure and complexity, and maintain unimpaired structure and complexity.*
- *Restore riparian condition and LWD recruitment, and maintain unimpaired conditions.*
- *Restore floodplain connectivity and function and maintain unimpaired floodplain connectivity and function.*

<u>Cow Creek</u>

The current status assessment for the Cow Creek redband trout population found that productivity was the population's highest risk of the four parameters assessed (high risk), followed closely by both abundance and spatial structure (high risk), and diversity (moderate risk).

The Technical Team identified limiting factors related to water quantity, water quality and habitat degradation as key concerns, with water quality being the most limiting. Poor water quantity, water quality and degraded habitat as threats are confirmed by the poor productivity, abundance and spatial structure scores from the assessment. The degraded condition of the habitat and water quantity/quality likely contributed to the lower diversity score as well.

Based on the findings of both the assessment and Technical Team's limiting factors, the following strategies should be pursued to improve the status of the Cow Creek population:

- *Restore and maintain water quantity sufficient to support the needs of redband trout.*
- *Restore and maintain water quality sufficient to support the needs of redband trout.*
- *Restore channel structure and complexity, and maintain unimpaired structure and complexity.*
- *Restore riparian condition and LWD recruitment, and maintain unimpaired conditions.*

<u>Riddle Creek</u>

The current status assessment for the Riddle Creek redband trout population found that spatial structure was the population's highest risk of the four parameters assessed (moderate risk), followed by productivity (moderate risk) and diversity (low risk).

The Technical Team identified limiting factors related to water quantity, water quality, habitat degradation, and habitat access as key concerns. Poor water quantity, water quality, degraded habitat, and habitat access as threats are confirmed by the moderately poor spatial structure and productivity scores from the assessment. The degraded condition of the habitat and water quantity/quality, as well as habitat access likely contributed to the lower diversity score.

Based on the findings of both the assessment and Technical Team's limiting factors, the following strategies should be pursued to improve the status of the Riddle Creek population:

- *Restore and maintain water quality sufficient to support the needs of redband trout.*
- *Restore and maintain water quantity sufficient to support the needs of redband trout.*
- *Restore degraded upland processes to minimize unnatural rates of erosion and runoff, and maintain natural upland processes.*
- *Restore passage and connectivity to habitats blocked or impaired by artificial barriers, and maintain unimpaired passage and connectivity.*
- *Restore channel structure and complexity, and maintain unimpaired structure and complexity.*
- *Restore riparian condition and LWD recruitment, and maintain unimpaired conditions.*

Blitzen River

The Blitzen River redband trout population is the most robust population in the Oregon portion of the Great Basin. The overall risk to the population is low, and the current status assessment found that spatial structure was the only VSP parameter that was not at very low risk (found to be at low risk).

The Technical Team identified limiting factors related to water quality, habitat degradation and habitat access as key concerns. Impacts from water withdrawals, degraded habitat and passage barriers support the conclusions that spatial structure is the greatest risk.

Based on the findings of both the assessment and Technical Team's limiting factors, the following strategies should be pursued to improve the status of the Blitzen River population:

- *Restore and maintain water quality sufficient to support the needs of redband trout.*
- *Restore and maintain water quantity sufficient to support the needs of redband trout.*
- *Restore degraded upland processes to minimize unnatural rates of erosion and runoff, and maintain natural upland processes.*
- *Restore passage and connectivity to habitats blocked or impaired by artificial barriers, and maintain unimpaired passage and connectivity.*
- *Restore channel structure and complexity, and maintain unimpaired structure and complexity.*
- *Restore riparian condition and LWD recruitment, and maintain unimpaired conditions.*

## 5.3 Actions to Address Strategies

Many of the strategies identified above are common between some, if not most populations. The actions necessary to address these common strategies are also similar between populations. ODFW does not have regulatory authority over the threats that the strategies address. As a result, the actions identified seek to work cooperatively with those agencies that do have regulatory authority to protect and maintain functioning habitat. ODFW will also be working with the watershed council, Natural Resource Conservation Service (NRCS), Soil and Water Conservation District (SWCD) and landowners to implement voluntary actions. The following sections identify actions to address each of the strategies identified above. For each population that has the same identified strategy, the listed actions will be encouraged to be implemented. In each population, it will be necessary to look at site-specific conditions to determine what types of actions should be implemented.

**5.3.1 Strategy: Restore and maintain water quality sufficient to support the needs of redband trout**.

*Action:* Malheur Watershed District staff (Staff) will work with Federal and private land owners to restore and maintain water quality sufficient to support the needs of redband trout within the Malheur Lakes SMU. Staff will continue to work with Federal agencies (Bureau of Land Management (BLM), United States Forest Service (USFS), United States Fish and Wildlife Service (USFWS)) to encourage management actions that will improve water quality on Federally owned land. Staff will work with willing private land owners to encourage management actions that will improve water quality on their land. Staff will collaborate with and support agencies (NRCS, SWCD, Oregon Department of Environmental Quality (ODEQ) or entities (Oregon Watershed Enhancement Board (OWEB), Oregon Department of Agriculture (ODA) that encourage improved water quality.

**5.3.2 Strategy: Restore and maintain water quantity sufficient to support the needs of redband trout.**

*Action:* Malheur Watershed District staff (Staff) will work with Federal and private land owners to restore and maintain water quantity sufficient to support the needs of redband trout within the Malheur Lakes SMU. Opportunities to restore and maintain water quantity sufficient to support the needs of redband trout are limited by climate, however Staff will work with private land owners to improve water quantity as options become available.

**5.3.3 Strategy: Restore degraded upland processes to minimize unnatural rates of erosion and runoff and maintain natural upland processes.**

*Action:* Malheur Watershed District staff (Staff) will work with Federal and private land owners to improve degraded upland processes and to minimize unnatural rates of erosion and runoff within the Malheur Lakes SMU. Staff will continue to work with Federal agencies (BLM, USFS, and USFWS) to encourage management actions that will improve degraded upland processes and reduce erosion on Federally owned land. Examples of such actions may include, but are not limited to: juniper thinning, grazing management, weed management, native plantings or other actions that will become available in the future. Staff will work with willing private land owners to encourage management actions that will improve degraded upland processes and reduce erosion on their land. Staff will collaborate with and support agencies (NRCS, SWCD, and ODEQ) or programs (OWEB, ODA-LAC) that encourage improved management of degraded upland processes and to reduce erosion. Examples of such actions may include, but are not limited to: juniper thinning, grazing management, weed management, native plantings or other actions that will become available in the future.

**5.3.4 Strategy: Restore passage and connectivity to habitats blocked or impaired by artificial barriers, and maintain unimpaired passage and connectivity.**

*Action:* Malheur Watershed District staff (Staff) will work with Federal and private land owners to restore passage and connectivity to habitats blocked or impaired by artificial barriers and maintain unimpaired passage and connectivity. Staff will use the Oregon Department of Fish and Wildlife fish passage priorities database to identify fish migration barriers and work with Federal agencies and willing private land owners to provide passage. Staff will encourage Federal agencies and private land owners to seek funding through grants or other sources to remove fish passage barriers on their properties.

**5.3.5 Strategy: Restore channel structure and complexity, and maintain unimpaired structure and complexity.**

*Action:* Malheur Watershed District staff (Staff) will work with Federal and private land owners to restore channel structure and complexity and maintain unimpaired structure and complexity. Staff will coordinate with USFS and BLM staff to prioritize channel habitat restoration areas for streams containing redband trout within the Malheur Lakes SMU; then work to implement restoration actions to improve channel structure and complexity, including encouraging beaver dams. Staff will work with willing private land owners, the watershed council, and OWEB to prioritize channel habitat restoration areas for streams containing redband trout within the Malheur Lakes SMU; then work to implement restoration actions to improve channel structure and complexity, including encouraging beaver dams.

Beaver dams change the hydrology of streams in ways that are beneficial for many fish species, including redband trout. Water depth is increased and current velocity is decreased upstream of beaver dams. The impounded waters upstream of a beaver dam can have wetted surface areas that are orders of magnitude greater than the pre-existing stream channel (Naiman et al. 1986), and shorelines that are more complex than other natural ponds (Naiman et al. 1988). Other key hydrologic functions of beaver dams are to dissipate stream energy, attenuate peak flows, and increase groundwater recharge and retention which in turn will increase summer low flows and elevate groundwater levels (Pollock et al. 2003). During flood events, beaver dams dissipate energy by forcing water to either flow through a tortuous path of small branches on the downstream side of the dam or through floodplain vegetation as water works its way back to the stream channel (Woo and Waddington 1990). These factors can combine to provide fish with ample foraging opportunities requiring less energy to utilize. Thus, beaver ponds tend to be more productive than un-dammed stream reaches in terms of number and size of fish (Pollock et al. 2003).

**5.3.6 Strategy: Restore riparian condition and LWD recruitment, and maintain unimpaired conditions.**

*Action:* Malheur Watershed District staff (Staff) will work with Federal and private land owners to restore riparian condition, LWD recruitment in appropriate areas, and maintain unimpaired conditions. Staff will coordinate/collaborate with USFS and BLM fisheries, range, and forestry staff to review grazing management plans, timber sales, and other projects that can affect riparian conditions near redband trout streams. Staff will work with willing private land owners, watershed councils, SWCD, NRCS, and OWEB to develop project on private property that will prevent further degradation of riparian conditions and begin the restorative processes; promote LWD recruitment in the future; or maintain unimpaired riparian conditions.

**5.3.7 Strategy: Reduce the impact of introduced species on redband trout populations and prevent the introduction of new non-native species.**

*Action:* Malheur Watershed District staff (Staff) will work with Federal and private land owners to reduce the impact of introduced species on redband trout populations and prevent the introduction of new non-native species. Staff will utilize current and future Statutes (ORS), rules (OAR), and policies to prevent new non-native fish species from being introduced into the Malheur Lake SMU. Staff will utilize strategic opportunities that are socially accepted to remove or reduce non-native fish populations in redband trout streams within the Malheur Lake SMU.

**5.3.8 Strategy: Restore floodplain connectivity and function and maintain unimpaired floodplain connectivity and function.**

*Action:* Malheur Watershed District staff (Staff) will work with Federal (USFS, BLM, USFWS) and private land owners to restore floodplain connectivity and function and maintain unimpaired floodplain connectivity and function.

**5.3.9 Strategy: Assess the status of populations and habitats with limited information.**

*Action:* Malheur Watershed District staff will work with land managers, the watershed council, the SWCD and others to gain access to streams that have had limited sampling in the past.

# CHAPTER 6

# RESEARCH, MONITORING AND EVALUATION

## 6.1 Introduction

Research, monitoring and evaluation (RME) are needed to understand and assess the status of redband trout, track progress toward achieving desired status, and provide information needed to refine management strategies and actions through the process of adaptive management. This chapter outlines the RME needs of this Plan as they pertain to the biological criteria (i.e. abundance, productivity, diversity, and spatial structure) defined in Chapter 2, and necessary to document and achieve desired status.

## 6.2 Research Needs

Uncertainty and a lack of information have been identified in this plan as limitations to our understanding of redband trout in the Malheur Lakes SMU and our ability to accurately assess their status. To help reduce uncertainty and improve the collection of information, research needs have been identified.

Research needs have been described in two broad categories: uncertainty research, and development research. Uncertainty research will seek to better understand the biological mechanisms and interactions that regulate the status of redband trout. This area of research will inform our understanding of how the fish use the habitat and aspects of their status.

The development research described below, seeks to develop better methods to monitor and evaluate the status of redband trout populations in order to have a degree of certainty as to the status of the populations, and to have an ability to detect progress towards the desired status goal of this plan.

### 6.2.1 Uncertainty Research Needs:

**Better understanding of the extent of potential spawning and rearing habitat for each population of redband trout in the Malheur Lakes SMU** – a better understanding of redband distribution will provide a greater ability to estimate population size and to more accurately identify limiting factors.

**Better understanding of how redband trout utilize habitat and their habitat preferences** – knowing how habitat is used and what is preferred will help to estimate the potential for population growth and better identify key limiting factors.

**Refinement of knowledge of the accuracy of field protocols to detect occupancy** - presence of individuals in samples is proof of occupancy, but absence cannot be proven. The problem is that frequency of “false” absences depends on the abundance and distribution of individuals, the sampling method and intensity, and the grain of sampling. This can be particularly problematic for species that are rare or patchily distributed or as populations decline in abundance and distribution leading to errors in estimates that vary with habitat and environmental conditions and species abundance.

**Better understanding of which life-history traits or other diversity parameters are the most meaningful measures of diversity, particularly in the context of future climate change impacts** - development of meaningful measures of diversity is difficult largely because of the lack of understanding of the expression of individual life history traits (the genetic and environmental effects) and the degree of correlation between those traits.

**Improved understanding of the impact that habitat related limiting factors and threats have relative to other potential limiting factors and threats over the entire life-cycle of redband trout populations** - needed to better inform decisions on where to prioritize funds and management actions.

**Determine the ability of manmade reservoirs to promote an adfluvial life history without causing deleterious effects to water quality and/or distribution** – needed to understand if current reservoirs can be beneficial, or modified to be beneficial, to the long-term conservation of redband trout.

#### 6.2.2 Development Research Needs:

**Development of efficient survey designs for assessing patchily-distributed populations based on understanding factors that influence annual variation in distribution (e.g. fish abundance and streamflow)** - traditional GRTS-based surveys can be misleading or costly to implement when populations exhibit patchy distributions. Understanding of factors that influence distribution will aid the design of more precise and efficient surveys. A more efficient and precise survey design must also be able to be implemented with current ODFW staffing in the Watershed District in order to provide reliable, routine monitoring of redband trout status.

**Development of new criteria to assess the status of redband trout and their habitats** – the viability criteria described in Chapter 2 cannot be re-evaluated under current staffing and funding realities. There are also significant uncertainties around the assumptions used in developing the current criteria. New criteria should be developed that provide a meaningful assessment of redband trout population and habitat health, while requiring a minimal amount of staffing and/or funding to evaluate status on a regular basis.

### 6.3 Monitoring Needs

Monitoring is necessary to track the status of the Malheur Lakes redband trout SMU and the effectiveness of this plan at moving the SMU towards the desired status. Monitoring can be labor-intensive, which makes it difficult to implement with only watershed district staff, but is necessary to conduct on a regular basis. The following sections describe the monitoring plan that is necessary to assess redband trout populations using the criteria described in Chapter 2 and ideas for alternative monitoring that would be implemented if resources are not available to conduct the monitoring plan.

### 6.3.1 Monitoring Plan

The field-based data necessary to estimate abundance, productivity, spatial structure, and diversity of redband trout populations based on the established criteria can generally be collected simultaneously, with a few exceptions. Map-based data with periodic ground-truthing will be necessary to estimate some aspects of the spatial structure criterion.

#### 6.3.1.1 Sample frame and sample site selection

The sample frame for each population should be the historic distribution of redband trout as defined in Chapter 2. Specifically, the historic distribution of redband trout is defined as all naturally connected stream reaches between the current upper extent of redband trout distribution downstream to natural lakes or to the point of natural stream cessation. In order to effectively quantify the productivity metric and the spatial structure metric it is essential that both wadeable and non-wadeable streams reaches remain in the sample frame.

A geographic information system (GIS) should be created and the sample frame should be mapped based on NHDPlus or NHDPlusV2 data. The sample frame should be divided into consecutive 100-m sample sites for wadeable stream reaches and consecutive 200-m samples sites for non-wadeable stream reaches; these sites will constitute a population of all possible sample sites. The starting location (geographic coordinates) for each possible sample site should be calculated from the GIS and these starting locations will be used as a list of finite resources from which to select from using a generalized random-tessellation stratified (GRTS) design (Stevens and Olsen 2004). The GRTS design will be used to select an ordered list of $N_{sites}$ sample sites from the sample frame; if the sample frame consists of both wadeable and non-wadeable stream reaches (hereafter reach types) then the GRTS design should be stratified by reach type and $N_{sites}$ sample sites should be selected from each reach type.

$N_{sites}$ will influence the precision and accuracy of abundance and density estimates; therefore, $N_{sites}$ should be based on conservation and recovery policy or recommendations regarding accuracy and precision criteria and information requirements for triggering management activities. In the absence of such policy or recommendations, empirical data from previous redband trout sampling in the Great Basin (Jones et al. 2007; Dambacher et al. 2009; Miller et al. 2010; Meeuwig and Clements 2014) may be used to guide selection of $N_{sites}$. For this document, the Planning Team chose to use available empirical data (Meeuwig and Clements 2014) as a general guideline for selection of $N_{sites}$ for wadeable streams. Data are not currently available for guiding selection of $N_{sites}$ for non-wadeable streams in the Malheur Lakes SMU; therefore, the Planning Team suggests similar guidelines be used for selecting $N_{sites}$ for wadeable and non-wadeable reach types.

On average, the precision of redband trout density estimates increases rapidly as $N_{sites}$ increases from two to about 30, the accuracy of redband trout density estimates increases rapidly as $N_{sites}$ increases from two to about 20, and the percent change in density that is detectable decreases rapidly as $N_{sites}$ increases from two to about 30 (Meeuwig and Clements 2014). As $N_{sites}$ increases beyond these values the marginal gain in precision, accuracy, and ability to detect changes in redband trout densities diminishes. Therefore, the Planning Team suggests that $N_{sites}$ for wadeable streams should equal 30. The Planning Team also suggests that this value be re-evaluated as additional data are collected because 1) long-term data sets spanning greater levels of environmental variation may provide greater inference into factors influencing the precision and accuracy of density estimates, 2) these values are based on a sample frame that likely did not include the full extent of redband trout within populations, and 3) slight modifications to sampling protocols used during previous studies (e.g., Jones et al. 2007; Dambacher et al. 2009; Miller et al. 2010; Meeuwig and Clements 2014) are proposed for future sampling. Additionally, smaller or larger values for $N_{sites}$ may be justified based on available population-specific data (see Supplemental Figure 2.4, 2.6, and 2.8 in Meeuwig and Clements 2014).

#### 6.3.1.2 Fish sampling gears and methods

Sample sites in wadeable reach types should be visited strictly following the order identified by the GRTS design, and the following methods apply to each wadeable sample site. Block nets should be placed at the upstream and downstream ends of the site to isolate it from immigration or emigration by target species.  Backpack electrofishing gear should be used to sample fish; electrofisher setting should follow standard guidelines (see Dunham et al. 2009). A multiple pass depletion methodology should be used and the number of passes conducted should follow guidelines based on depletion estimate assumptions (see Connolly 1996). For each electrofishing pass a three person crew (one electrofisher and two netters) should electrofish in an upstream direction starting at the downstream block net and ending at the upstream block net (Dunham et al. 2009) capturing all fish that are encountered. In addition to multiple pass depletion sampling, mark-recapture methodologies should be used at the first 20% of the sample sites visited. For these sample sites block nets should be established as above, a single electrofishing pass should be conducted as above, and all captured redband trout should be marked (e.g., fin clip, PIT tag, etc.) and returned to the stream. Block nets should be left in place for about 24-h and the site should be sampled using the multiple pass depletion methodology as above; recapture of marked fish should be noted.

Sample sites in non-wadeable reach types should be visited following the order identified by the GRTS design, and the following methods apply to each non-wadeable sample site. Sites should be sampled in an upstream to downstream direction using raft or boat mounted electrofishing gear (Curry et al. 2009) and using appropriate electrofishing settings. A single pass will be made through each site by a boat operator and two netters and all fish encountered should be captured. The first 20% of the sample sites on the ordered site list should be sampled again after about 24-h.

All fish sampled should be identified to species, counted, and measured for length (forklength); for non-target species (i.e., species other than redband trout), if greater than 100 individuals are sampled from a site only measure the first 100 encountered. A small fin clip (about 5 mm x 5 mm) should be collected from all redband trout > 60 mm for genetic analysis, and a scale sample should be collected from all redband trout for age and growth analysis.

Data generated from electrofishing surveys will be used to evaluate:

- Abundance – Depletion sampling in wadeable reach types will be used to estimate abundance and density of redband trout; mark-recapture sampling will be used to evaluate bias associated with depletion estimates. Site specific abundance and density estimates will be extrapolated to the extent of the wadeable reach type portion of the sample frame (Chapter 2). These data will not be formally combined with data from non-wadeable reach types; therefore, the abundance estimates should be considered as minimum abundance if redband trout are present in non-wadeable reach types.
- Productivity – Redband trout length-frequency data will be quantify the proportion of redband trout < 100 mm and the proportion of redband trout of redband trout > 100 mm that are also > 200 mm (Chapter 2). These calculations will be performed for each reach type and an overall estimate will be obtained.
- Spatial structure – Redband trout distribution data will be used to quantify the proportion of historically occupied habitat that is currently occupied (Chapter 2).
- Diversity – Redband trout length data will be used to qualify the presence of multiple life-history forms (Chapter 2).

#### 6.3.1.3 Physical habitat sampling data

Physical habitat data should be collected at all sample sites in wadeable reach types. Physical habitat data should be collected at transects spaced every 10-m along the thalweg of the site starting at 5-m upstream of the downstream block net location. At each transect the wetted channel width should be measured, stream depth should be measured at 0.25, 0.50, and 0.75 times the wetted channel width, and the maximum channel depth should be measured. Additionally, the maximum depth of the entire sample site should be measured, substrate composition of the entire site should be estimated (i.e., percent fines, gravel, cobble, and boulder), the percent of the site with undercut banks should be estimated, and the number of pieces of large woody debris (i.e., at least 10 cm long) within the wetted channel should counted.

Physical habitat sampling data will be used to evaluate:

- Spatial structure – The quality of currently occupied habitat (Chapter 2).

#### 6.3.1.4 Map-based data and ground-truthing

Field-based fish sampling data (specifically redband trout distribution data) should be integrated with the GIS used for mapping the sample frame (see above), digital elevation data, and currently available fish passage barrier data. These data will be used to quantify characteristics of redband trout populations necessary for evaluating the spatial structure criterion. Additionally, ground-truthing of available fish passage barrier data should be conducted by walking the entire sample frame and confirming or refuting the presence of putative passage barriers and identifying currently un-mapped passage barriers. Ground-truthing will also be used to identify the presence of suitable rearing habitat for migratory redband trout (Chapter 2). Ground-truthing fish passage barrier data should be conducted during the first year of any nine-year assessment of a redband trout population, and periodically thereafter if deemed appropriate.

Map-based data and ground-truthing will be used to evaluate:

- Spatial structure – Stream drainage pattern, the current greatest continuous stream distance relative to the distance of historically occupied habitat (in conjunction with fish sampling data), and availability of habitat that can foster a migratory life history.
- Diversity – Elevational distribution of redband trout (in conjunction with fish sampling data).

The monitoring plan outlined above requires a dedicated team of biologists sampling all nine populations over the summer months in order to gather the necessary data to feed into the viability criteria defined in Chapter 2. Of the nine populations, two populations have some limitation on ODFW being able to access the stream to monitor those redband trout populations.

### 6.3.2 Alternative Monitoring

A critical research need identified in the Research Needs section above (Section 6.2) was the development of better and more efficient survey designs for monitoring redband trout population status. The current status viability criteria outlined in Chapter 2 are the most appropriate criteria ODFW could develop with the data the Planning Team had for the populations at the time of plan development. However, the data that was used to develop the criteria were gathered through some extensive sampling over a number of years. Once this plan is adopted, it will be extremely difficult for ODFW to repeat the extensive sampling as regular monitoring (as outlined above). If alternative monitoring designs are identified, new criteria would be developed and cross-walked with the current status criteria identified in Chapter 2 so future status can be assessed against the desired status, critical status and non-viable status criteria described in Chapter 3.

## 6.4 Evaluation Needs

Evaluating the effectiveness of actions taken to improve or maintain the status of a redband trout population is invaluable in assuring the success of this conservation plan. It is currently not possible to estimate the conservation benefit a redband trout population will receive from implementing any given action called for in Chapter 5. In order to understand how many actions need to be implemented or how big of an area needs to be treated in order to achieve the desired status outlined in Chapter 3, it will be important to evaluate the effectiveness of actions taken.

Effectiveness monitoring is often used to evaluate the effectiveness of an action taken. Efforts are underway to conduct effectiveness monitoring of actions taken to recover federally listed salmon and steelhead in the Pacific Northwest. It may be possible to gain insight into the effectiveness of actions targeted at improving the status of redband trout by inferring how results from effectiveness monitoring of actions affecting steelhead might translate to redband trout. As results of effectiveness monitoring of steelhead actions become available, ODFW will evaluate if implications can be made to actions taken for redband trout.

If ODFW analysis of the results of effectiveness monitoring of steelhead actions finds that the results cannot inform the expected effectiveness of redband trout actions, ODFW will pursue opportunities to conduct effectiveness monitoring of actions implemented in the Malheur Lakes SMU as funding and staffing allow. This monitoring may take the form of an intensively monitored watershed that is treated and monitored to provide reasonably accurate estimates of the response of the actions on the habitat and the fish. Site-specific effectiveness monitoring may also be used to monitor a particular action's effect at a site in lieu of an intensively monitored watershed. Any site-specific effectiveness monitoring will be dependent on the funding and staffing abilities of ODFW.

Regardless of the approach to evaluating the actions called for in this plan, the results of any form of effectiveness monitoring must be incorporated into future decisions about what actions need to be taken and where. The management strategies outlined in Chapter 5, and their associated actions, are hypotheses about what is limiting the fish and what should be done to address those limitations. ODFW is committed to incorporating effectiveness monitoring results into the adaptive management process outlined in Chapter 7 to ensure this conservation plan can direct actions to improve the status of redband trout populations and lead to achievement of the desired status.

# CHAPTER 7

# IMPLEMENTATION AND ADAPTIVE MANAGEMENT

## 7.1 Introduction

This plan has described the current status of the Malheur Lakes redband trout SMU, and has also described the desired status that ensures their continued existence and also allows for them to contribute ecological, social and cultural benefits to the areas they inhabit. Chapter 4 has identified the key and secondary factors that are limiting the redband trout populations from achieving their desired status, and Chapter 5 has outlined the types of actions that are necessary to address those limiting factors and achieve desired status. Chapter 6 identifies the monitoring, evaluation and research that are needed to assess progress towards achieving desired status, determining how effective implemented actions are, and understanding uncertainties. The final piece of this plan is to identify a process to implement all aspects of this plan, while also providing a feedback loop that will allow for modifications to the proposed actions, or the plan's goals, if warranted.

## 7.2 Implementation

ODFW will implement all of the actions identified in this plan within funding and staffing constraints. To achieve the level of improvement necessary to reach the desired status of this plan, it will be necessary for ODFW to work collaboratively with local groups and landowners to improve, or lessen the impact of, those factors that have been identified that are most limiting. ODFW is committed to partnering with groups and individuals to help design, seek funding for, and execute projects that implement the actions called for in this plan.

To help facilitate collaborative work that addresses the key and secondary limiting factors identified in this plan, the plan will be shared with land managers, watershed councils, SWCDs, NRCS and the public. ODFW will work with these groups and landowners to identify those projects that are feasible to implement and will be effective at addressing the limiting factors identified for each population. Funding will be sought through the Oregon Watershed Enhancement Board and other funding sources, with ODFW providing in-kind match where possible.

## 7.3 Adaptive Management

The scarcity of available data on redband trout in the Malheur Lakes SMU has been described in previous chapters. As a result, the limiting factors identified in this plan and the management strategies and actions identified as necessary to achieve the desired status should be considered working hypotheses that need to be tested. ODFW will utilize an adaptive management framework to assess the validity of the hypotheses and to track progress towards achieving desired status.

The adaptive management framework will begin with a set of actions to implement and a presumed outcome from implementing those actions. Collection and analysis of information as it becomes available will then be used to assess whether the presumed outcomes occurred, or whether the expected outcome of the actions did not occur. Depending on the analysis of action effectiveness, effective actions will continue to be implemented, or ineffective actions will be discontinued and a new set of actions will be developed that have been informed by the knowledge gained from assessing previous action effectiveness.

Information related to fish status will be considered in the context of multi-year trends to determine if the most recent information confirms a downward, upward or stable trend in status. The quality of the information will also be factored into the analysis to ensure any actions taken, or discontinued, are appropriate. ODFW will summarize this new information annually and describe any modifications to implementing actions that are found to be necessary to achieve desired status. These annual summaries will be posted for public consideration on a soon-to-be-developed Redband Conservation Plan website.

If information suggests that the status of any redband trout population is declining, ODFW will consider the causes and severity of the decline in suggesting any additional actions to be implemented. Members of the Technical Team, watershed councils, SWCDs, NRCS and other interested groups will be informed of any confirmed decline in status, and the additional actions that have been identified to seek to reverse the decline.

As discussed in Section 3.5, every 12 years (approximately four redband trout generations), the status of populations and SMU will be re-assessed, with a possible adjustment of actions in this Redband Conservation Plan if needed to achieve Plan objectives. If the status or goals of the SMU and strategies to achieve desired status need to be substantively changed or modified as a result of this broader re-assessment, a public process will be undertaken, with Oregon Fish and Wildlife Commission approval necessary for such changes.

Modifications to this plan are required if either SMU becomes listed under the federal Endangered Species Act or if a status assessment determines an SMU has become non-viable.

## 7.4 Outlook

The Oregon Great Basin in southeast Oregon is a challenging environment for stream-dwelling trout to persist within. Yet, redband trout still persist after centuries of existence in this arid climate. Despite long periods of drought and populations that are geographically isolated from each other, the species has maintained a presence in most of the watersheds they historically occupied. The resilience of these fish is remarkable.

The alteration of their habitats over time has reduced redband trout distribution in their historical watersheds. Projected impacts from climate change will likely further reduce the distribution of redband trout in the Malheur Lakes SMU. Longer and more intense droughts are likely and stream water temperatures will probably increase. It will be important for redband trout in these areas to remain resilient. It will also be imperative that the quantity and quality of the current habitat that they occupy remains stable, if not increases, for these fish to persist for centuries into the future.

This plan outlines the strategies and actions that are believed to be necessary to ensure the conservation of redband trout in the Malheur Lakes SMU. All of the actions are outside of the regulatory authority of ODFW, and can only be implemented voluntarily by those living with the fish – local watershed councils, SWCDs, NRCS, land managers, and landowners. ODFW will encourage and support the implementation of these necessary actions and will work with local groups to find ways to provide incentives to landowners that will allow the fish in each population to benefit from the actions. ODFW will also explore all options to develop methods that allow a better understanding of the fishes' status and what is most limiting their survival. It will be challenging to achieve the desired status for the Malheur Lakes SMU of redband trout identified in this plan, but Oregon's track record of local, voluntary efforts through the Oregon Plan provide hope that these fish can be conserved for present and future generations.

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# APPENDIX 1

# POPULATION RISK ASSESSMENTS

**Introduction**
This appendix describes the current status of Great Basin redband trout populations in ODFW's Malheur Lakes SMU. To understand the current status of the redband trout populations, an assessment using measurable criteria is necessary, and some standard needs to be established to compare the results against to put the results into some context. A definition of viability in terms of a set of measurable criteria was developed for the assessment conducted here and is described below.

The status assessment serves as the foundation of the conservation planning process in which populations are identified that are not viable or do not achieve levels of desired status. For such populations, the assessment provides the basis for naming limiting factors and threats to be addressed by specific conservation actions. Given that all populations are rated using the same metrics and protocols, conservation actions can be easily prioritized within and between populations. Additionally, this analysis identifies data gaps where more empirical information is necessary in order to fully describe population dynamics and more accurately assess status.

Viability is defined by the balance between the rate of recruitment and rate of loss in a population such that the probability of persistence for a population remains constant or increases over a given period of time (Ruggiero et al. 1994). Furthermore, the definition of viability, as employed by this plan, implies a population exists at such a level where the natural ecological and evolutionary processes can continue to operate through time (Fausch et al. 2006). A viable population has a negligible risk of extinction due to threats from demographic variation, local environmental variation, and changes in genetic diversity (McElhany et al. 2000). A population at high risk of not being viable is one where the probability of persistence is quite low and the population may potentially go extinct, whereas a population at low viability risk has a high probability of being viable through time. For this conservation plan the time period of concern is the next 100 years. While somewhat arbitrary, 100 years represents a period long enough to encompass essential long-term processes (e.g. environmental cycles, genetic processes, and results of recovery actions) but short enough to appropriately model and evaluate population trends (McElhany et al. 2000).

ODFW's Native Fish Conservation Policy (NFCP) (ODFW 2002) recommends a suite of biological attributes by which to assess the status and viability of all native fish populations. These attributes include distribution, abundance, population diversity, connectivity, survival, population growth and a forecast of persistence. Commonly conservation plans will evaluate many of these attributes collectively using a population viability analysis (PVA) in which ecological relationships and demographic parameters are incorporated into a mathematical model that predicts population trend and extinction probabilities. Such an approach provides a quantitative evaluation of risk with a measure of uncertainty. A formal PVA requires long-term datasets describing life-history, population dynamics and habitat use, all of which are unavailable or inadequate for Oregon's Great Basin redband trout populations. Thus an accurate and reliable forecast of persistence is not feasible. Instead population viability in this plan is assessed using a suite of metrics incorporating many of the recommendations and guidelines outlined in McElhany et al. (2000). A guiding document for the conservation of salmonid populations, McElhany et al. (2000) describes four Viable Salmonid Population (VSP) attributes by which to effectively assess viability; abundance, productivity, spatial structure, and diversity. Although McElhany et al. (2000) made recommendations specifically addressing anadromous forms, the biological principles therein are also fundamental to interior species. Many of the population attributes identified in the NFCP are captured within the four VSP parameters. Distribution and connectivity are elements of spatial structure, whereas population growth and survival are aspects of productivity.

The suite of metrics developed to assess Great Basin redband trout populations minimally examines the four VSP parameters while maximizing the limited empirical data and supplementary information available (Appendix 2). For example, in the absence of datasets directly pertinent to recruitment, productivity is evaluated using a length frequency analysis of fish captured during abundance sampling. In this case the metric is assessed using surrogate measures based on empirical data. Thus while a number of the metrics are not direct measurements of each criteria the biological principles are retained.

The viability analysis was objective, repeatable and transparent; however the results do not provide a quantitative measure of risk and an associated degree of certainty. Instead, risk was evaluated qualitatively based generally on the following basic tenets from McElhany et al. (2000):

1. Bigger is better than smaller,
2. High reproductive rates are more secure than lower reproductive rates,
3. Connected is better than isolated, and
4. More diverse is better than less.

This population assessment represents our most informed attempt at describing population viability. The data gaps and assumptions identified therein results in a high degree of uncertainty. Thus this assessment and the metrics employed are intended to serve as a starting point for an iterative process to further refine the assessment methodology. The data gaps and uncertainties identified within this assessment will guide current and future research to provide assistance in determining meaningful metrics, defining appropriate thresholds and efficiently collecting pertinent data, all of which will result in a more accurate, meaningful, and robust assessment.

**Criteria**

Abundance

The goal of the abundance criterion is to identify populations at high risk of suffering the deleterious effects of small population size. A viable population must be large enough to avoid the effects of inbreeding, survive environmental variation, be resilient to disturbance and maintain historical spatial structure. Unfortunately data are not available to adequately determine a minimum threshold above which a population is not subject to these effects. Given this data gap, this conservation plan has established a minimum abundance threshold of 2,500 individuals based on widely accepted findings in the conservation literature, modeling exercises, empirical research on redband trout and other trout species, and best professional judgment. In addition, data sufficient for accurately estimating population size do not exist for all populations. Some populations are characterized only by a handful of density estimates, thus the metric includes a framework to rank risk according to mean density while acknowledging the high degree of uncertainty associated with such an evaluation.

**Objective –** Maintain a population size > 2,500 age 1+ fish and a density > 50 fish/mile

**Table A1-1 Metric – Abundance and density of age 1+ fish**

| Fish / mile | Risk | Score |
|---|---|---|
| > 400 (248 / km), total pop >2500 | Very Low | 5 |
| 50 - 400, total pop >2500 | Low | 4 |
| < 50 (31/km), total pop >2500 | Moderate | 3 |
| < 50 (31/km), total pop <2500 | High | 1 |

The abundance metric was evaluated using a 2008 dataset designed to estimate population level distribution and abundance (Miller et al. 2010). Drawing from a sample frame of potential distribution, approximately 30 sites were surveyed in each population. Sites were randomly selected and spatially balanced to ensure a representative sample. Estimates of redband trout density were obtained at each sample site and extrapolated to the extent of the sample frame to obtain an overall approximation of population size with measures of confidence (Miller et al. 2010). Due to extremely limited distributions (<20 km), four populations were combined into one strata for logistical reasons. Evaluation of abundance for these populations was based on less robust abundance estimates, a measure of mean density, and/or professional judgment. Justifications for these judgment calls are outlined in the results.

Productivity

The intent of the productivity criterion is to identify populations in which productivity rates do not support net replacement or are not large enough to allow the populations to rapidly return to abundance targets after short-term perturbations. Ideally this plan would assess productivity using a measure of population growth rate over the entire life cycle and, in the best of all circumstances, also include measures of stage specific productivity (McElhany et al. 2000). In regard to Great Basin redband trout populations, data are not available to directly assess productivity rates and quantify population growth. Trends in abundance do not exist at the population scale, and at the SMU scale reliable abundance estimates only exist for years 1999 and 2007-10 (Dambacher et al. 2009, Miller et al. 2010). These data are not adequate to evaluate long term trends and fluctuations in population abundance and productivity in light of natural climatic cycles. In the absence of typical measures of productivity, length-frequency histograms are employed as a general indicator of potential population growth (Appendix 2). While length frequency analysis does not provide an absolute measure of population replacement, it can identify instances when recruitment may be diminished. Populations in which the proportion of fish <100mm is continually low, may be suffering from sustained declines in recruitment that could translate into detectable declines in abundance. Similarly the absence of large adults could suggest a loss of significant life history traits, compromised long term survival, and provides an indication of potentially decreased productivity. In lieu of an empirical measure of productivity, length frequency analysis is employed to identify populations of concern that warrant further evaluation.

The productivity metric considers the proportion of the population in two size classes, < 100mm and >200mm. Length at maturity for these populations is unknown and likely varies widely between populations. Based on research in the high desert of Idaho (Schill 2009) this assessment assumes fish <100mm are juveniles and fish >200mm are mature (Appendix 2). Populations are scored according to the proportion of the fish sampled <100mm and the proportion of fish >100mm that are > 200mm (sensu Zoellick *et al.* 2005). A population is first scored according to the percentage of juveniles. A point is added to or subtracted from that score if the proportion of fish >100mm that are >200mm is greater than 15% or less than 7% respectively.

**Objective –** Maintain a minimum proportion of juveniles and large adults, indicative of long term survival and reproductive success.

**Table A1-2 Metric – Proportion of population in smallest (<100mm) and largest (>200mm) size classes.**

| % of fish <100mm | Juvenile Score | % of fish >100mm that are >200mm | Adult Score | Risk | Final Score |
|---|---|---|---|---|---|
| >25% | 5 | > 15% | +1 | Low | 5 |
| 25 - 15% | 3 | 15 – 7% | 0 | Moderate | 3 |
| <15% | 1 | < 7% | -1 | High | 1 |

The productivity metric was evaluated using size frequency histograms of fish captured during 2007-2010 population sampling (Miller et al. 2010). Incorporating multiple years of sampling into the analysis mitigates the effect of temporal or spatial fluctuations in populations and sample timing (Platts and Nelson 1988, sensu Zoellick 2005). This analysis does not provide a measure of confidence. Instead, the sample size, both in terms of the number of fish and number of sites visited, serves as an indicator of certainty. Measures from populations sampled with a large sample size are assumed to have a higher degree of certainty than those with a small sample size. In populations where data are not available or sample size was particularly low the productivity criterion was evaluated based on best professional judgment. In these instances intrinsic potential of the habitat, prior sampling (pre-2007), and anecdotal observations were taken into account. Justifications for these judgment calls are outlined in the results.

Spatial Structure

The goal of the spatial structure criteria is to identify populations where alterations to the historical physical template negatively impact the natural spatially mediated processes necessary to maintain population level diversity and viability. Given that little information is available on how spatial structure relates to salmonid viability in general (McElhany et al. 2000) and biologists are unable to describe the spatial structure of redband trout populations specifically, this plan has developed a composite metric to assess the potential for a complex structure to exist (Appendix 2). The intent is to identify and conserve processes, such as dispersal, life history, and linkages between landscapes that likely contribute to persistence regardless of the actual spatial structure exhibited by a population (Rieman and Dunham 2000). Thus, by nature, the metric primarily considers landscape-scale processes as opposed to empirical population-specific data. This status assessment assumes historical populations survived many years of environmental change and therefore must have had adequate structure and diversity to remain persistent. Therefore, when managing for persistence and viability the goal is to preserve elements of historical spatial processes since it is not known whether a novel structure is sustainable (sensu McElhany et al. 2000).

The viability criterion for spatial structure evaluates two components separately, habitat availability/suitability and connectivity. Each component is comprised of 2 or 3 metrics assessing different facets of that component. The metrics are scored on a continuum where large, connected, populations in suitable habitats are assumed to be relatively persistent and those that are small, isolated, and in degraded habitats are at some risk of extinction (Dunham and Rieman 2000). Habitat availability is described by measures of quantity, quality and configuration, whereas connectivity considers the accessibility of historical distribution and presence of habitat suitable for rearing migratory fish.

*Habitat Availability*

**Objective** – Maintain natural distribution through habitat availability.

**Habitat Quantity**

This metric provides a measure of how much historical habitat is currently occupied. Following the guidelines provided by McElhany et al. (2000) the goal is to maintain the historical template of available habitat and ensure habitat patches are not destroyed faster than they are naturally created. Thus populations whose current distribution is equivalent to historical distribution are considered to be at very low risk of not being viable, whereas populations occupying less than 50% of the historical distribution are at high risk.

**Table A1-3 Metric - Percent of historical distribution currently occupied.**

| % stream distance | Risk | Score |
|---|---|---|
| > 90% | Very Low | 5 |
| 75-89 % | Low | 4 |
| 50-74 % | Moderate | 3 |
| <50% | High | 1 |

Current distribution is based on the potential year around distribution as represented by the sample frame employed by ODFW's Native Fish Investigation Project (NFIP) (Miller et al 2010). The NFIP redband trout sample frame includes wade-able streams or reaches that are sample-able by backpack electrofishing and therefore may underestimate the actual potential distribution in basins where redband trout occupy larger rivers (Strahler's stream order ≥4, Strahler 1952) year around. The sample frame is unverified in the few streams where sampling has not occurred due to a lack of access to private property. Current distribution is calculated as the proportion of the sample frame occupied during the 2008 population level sampling effort (Miller et al 2010).

Historical distribution of redband trout is virtually unknowable and therefore undocumented (Schill 2009). For the purpose of this assessment the current upper extent of redband trout is assumed to be very similar to that of 200 years ago. Historical distribution is defined as all naturally connected reaches between the current upper extent downstream to natural lakes or the point of natural dissipation. The uncertainty associated with this measure is quite high, particularly in smaller disconnected basins where the natural point of dissipation has been altered by climatic cycles and land use activities and in larger basins where historical secondary channels have been altered or eliminated.

**Habitat Quality**

High quality habitat is fundamental to the persistence of Great Basin redband trout. Habitat quality is assessed with a limiting factors habitat model, HabRate, which was developed by ODFW's Aquatic Inventory Project to assess potential quality of in-stream habitat for steelhead trout (Burke et al. 2010). HabRate is a logic based model that evaluates survey reaches based on their suitability for each life history stage (spawning to emergence, 0+ summer rearing, 0+ overwintering, 1+ summer rearing and 1+ overwintering). It incorporates a collection of stream level habitat variables into a series of 'if-then' statements that evaluate potential limiting factors. A comprehensive literature review of steelhead and rainbow trout habitat requirements provided the basis for these criteria (Burke et al. 2010). While the model was designed specifically for steelhead trout in the Deschutes River Basin it was intended to be applicable to basins of the Pacific Northwest. Given the depth of the literature review, the general lack of interior redband trout specific studies, and the varied habitat use by redband trout, the criteria as written for Deschutes Basin steelhead trout are considered the best starting point for Great Basin redband trout (Appendix 2). Future research concerning specific habitat needs will be incorporated into the model when available.

Model output provides a general habitat rating of good, fair, or poor for each life history stage at each survey reach. This habitat assessment incorporates spawning/emergence, 0+ summer, and 0+ winter rearing scores into a final habitat score (Appendix 2). A population is then described by the proportion of sample sites in each classification. Populations exceeding 50% of sites classified as in good condition are considered at very low –to-low risk of not being viable. Populations exceeding 30% of sites classified as poor habitat quality are considered at high risk of not being viable.

**Table A1-4 Metric – Percentage of habitat rated as in good, fair or poor condition based on the outcome of the HabRate model**

| Good | Fair | Poor | Risk | Score |
|---|---|---|---|---|
| 75% | Up to 25 % combine | | Very Low | 5 |
| > 50% | < 50% combine | | Low | 4 |
| <50% | > 70% | < 30% | Moderate | 3 |

| | | | | |
|---|---|---|---|---|
| 0% | < 70% | > 30% | High | 1 |

ODFW possesses three datasets that include in-stream habitat variables for streams throughout the Malheur Lakes SMU, though each dataset has its own limitations.

1. ODFW's Aquatic Inventory Project has completed comprehensive basin surveys for various streams throughout the SMU. At the stream habitat unit scale these surveys include extensive measures of habitat elements, a wood inventory, and riparian descriptors. Some of these surveys are scaled-up to measure geomorphic reach variables. However, these data have limited spatial coverage or are in need of updating. In the Malheur Lakes SMU the total stream distance surveyed in each redband trout population is limited, totaling only 9% (167 Km) of the historical distribution for the SMU.
2. The 1999 dataset (Dambacher et al. 2009) consists of habitat surveys conducted at randomly selected, spatially balanced sample sites and includes the same habitat descriptors as the basin surveys. However it is designed to describe stream habitat at the SMU scale, not the smaller population scale. In addition this dataset is also greater than 10 years old.
3. The 2007-10 (Miller et al. 2010) dataset also consists of surveys at randomly selected sample sites and during years of intensive sampling is designed for inference at the population scale. It includes a limited set of habitat measurements that collectively describe habitat complexity as it relates to the capture efficiency of 2-pass removal electrofishing protocol. The dataset is not intended to be a comprehensive inventory of habitat units and associated parameters. Many of the data (e.g., depth and substrate) are collected along regularly spaced transects and cannot be expressed at a finer habitat unit level resolution.

The Planning Team chose to apply HabRate to the 2007-2010 dataset because it was the most current dataset available and representative at the population scale. All sites surveyed between 2007 and 2010 were incorporated into the model except for annual sites (sites visited each year) where only the most recent survey was included. Given that the sites are representative, the overall score can be extrapolated to potential redband trout distribution within each population.

The disadvantage of employing this dataset is the lack of variables measured at the habitat unit scale. To accommodate these data the HabRate model was modified by removing measures of pool area, a comprehensive boulder count, and an estimate of gradient (Table A1-5). In addition calculations of depth and the classification of large wood were modified to accommodate the available measurements. HabRate also has the capacity to incorporate temperature and flow measurements but these variables were not included due to a lack of data at the population and sample site levels.

**Table A1-5. In-stream habitat variables included for spawning and age 0+ life stages in the HabRate limiting factors model for steelhead trout (Burke et al 2010). Modifications describe changes made to accommodate the 2007-2010 dataset (Miller et al 2010).**

| | Good | Fair | Poor | Modifications |
|---|---|---|---|---|
| ***Spawning, egg survival, emergence*** | | | | |
| Substrate | | | | |
| Fines | ≤ 10 % | 10 - 20 % | > 20% | |
| Gravel | ≥ 30 % | 15 - 30 % | < 15 % | |
| Cobble | 10 - 30 % | 30 - 60 % | < 10 %, > 60 % | |
| Habitat (Pool Tailouts) | 40 - 60 % | 20 - 40 % | < 20 % , > 60% | removed from model |
| Residual Pool Depth | ≥ 0.2 m | | No Pools | max depth – mean depth |
| Temperature | 6 - 12.5°C | 4- 6, 12.5-16°C | < 4°C, > 16°C | not included |
| Flows | 100 - 50 % base flow | 25-50% base flow | < 25 % base flow<br>> annual base flow | not included |
| ***Age 0+ Summer Rearing*** | | | | |
| Substrate | | | | |
| Fines *(interstices and productivity)* | ≤ 10 % | 10 - 30 % | > 30% | |
| Cobble & Boulder *(cover)* | ≥ 20 % | 10 - 20 % | < 10 % | |
| Pool Area | 40 - 60 % | 20 - 40 % | < 20 % , > 60% | removed from model |
| Cover (*at least one true*) | | | | |
| % Undercut | ≥ 15 | 10 –15 | < 10 | |
| LWD / 100m | ≥ 20 | 10 – 20 | < 10 | wet pieces / 100m |
| Boulders / 100m | ≥ 20 | 5 – 20 | < 5 | removed from model |
| Temperature | 10 - 13°C | < 10, >13°C | Lethal levels* | not included |
| Flows | 100 - 50 % base flow | 25-50% base flow | < 25 % base flow | not included |
| ***Age 0+ Overwintering*** | | | | |
| Substrate | | | | |
| Fines *(interstices)* | ≤ 10 % | 10 - 30 % | > 30% | |
| Cobble & Boulder *(cover)* | ≥ 20 % | 10 -20% | < 10% | |
| Pool Area | 40 - 60 % | 20 - 40 % | < 20 % , > 60% | removed from model |
| Cover (*at least one true*) | | | | |
| % Undercut | ≥ 15 | 10 –15 | < 10 | |
| LWD / 100m | ≥ 20 | 10 – 20 | < 10 | wet pieces / 100m |
| Boulders / 100m | ≥ 20 | 5 – 20 | < 5 | removed from model |
| Pool Complexity (see below) | Good | Fair | Poor | |
| Gradient | < 4% | ≥ 4 % | | removed from model |
| Flows | 100 - 50 % base flow | 25-50% base flow | < 25 % base flow | not included |
| **Pool Complexity** | | | | |
| Scour Pool Depth | | | | |
| Wetted width ≤ 10m | > 0.6 | | < 0.6 | |
| Wetted width > 10m | > 1 | 0.6 - 1 | < 0.6 | |
| Large Wood (pieces) | ≥ 2 | 1 - 2 | No wood | wet wood |
| Undercut | >20% | 5 - 20% | <5% | removed from model |

| | | | | |
|---|---|---|---|---|
| Boulders in pools | >15% | 8 - 15% | <8% | removed from model |

This analysis represents our best opportunity to evaluate redband trout habitat quality because it is based on an objective data-based model designed for Oregon trout species and incorporates recent data collected at sample sites representative at the population scale. However, the analysis contains many ambiguities and uncertainties. Primarily, the model was not designed specifically for the dataset the Planning Team applied. A comparison of the 1999 dataset analyzed with both the original and partial model shows the partial model is negatively biased. The partial model rated 22% of the sites as one category lower (worse condition) than the full model ($\chi^2 = 13.876$, $P<0.001$) - fewer sites (14%) were rated as good, and more (8%) as poor. In addition, this evaluation is only representative of habitat within the current distribution of redband trout and does not apply to stream reaches within their historical habitat but outside current distribution. Similarly, even though the 2007-10 dataset is designed to assess status at the population scale many of the small populations are still only represented by a few sample sites. As a result the assessment of these populations results in even lower confidences. Thus, due to these caveats the assessment of habitat quality is identified in the RME chapter as being a critical uncertainty. Emphasis needs to be placed on collecting appropriate habitat measures during current field efforts in order to adequately and confidently parameterize and apply the HabRate model to Great Basin redband trout populations.

**Habitat Configuration**

This metric addresses the inherent risk to the population associated with the natural configuration of the system in which it resides. A highly dendritic system is comprised of a large proportion of low order headwater streams which increases the potential for multiple spawning areas (patches), and is considered a risk averse configuration. A population occupying a linear stream system has limited ability to establish multiple spawning areas and is at high risk of extinction due to stochastic events.

The evaluation of the configuration of habitat considers both stream order and the number of tributary junctions. Stream order and the number and location of tributary junctions are indicative of the degree of bifurcation. Given the vagaries of digital stream mapping, particularly in small desert streams, neither measure is singly adequate.

**Table A1-6 Metric – spatial arrangement of habitat patches.**

| Stream Order | # of Junctions | Risk | Score |
|---|---|---|---|
| > 5 | > 5 - Dendritic | Very Low | 5 |
| 4 | 3-4 | Low | 4 |
| 3 | 1-2 | Moderate | 3 |
| 1 - 2 | 0 (linear) | High | 1 |

The assessment of the configuration metric was based on the stream habitat considered to be available to each redband trout population. This is defined as the potential distribution (NFIP sample frame) plus any connected stream segments classified as perennial in the USGS National Hydrography Dataset (NHD 1:24K). The NHDPlus dataset provides a Strahler stream order classification for each stream system. In instances where the stream order did not equate to the same risk rating as the number of tributary junctions, the score was chosen based on best professional judgment, with care to error on the side of caution. For instance, populations where junctions occurred high in the system were rated at higher risk than those with the same number of junctions but lower in the system. Rationale for all judgment calls are outlined in the results.

*Within Population Connectivity*

**Objective** – Maintain historical levels of connectivity.

**Accessible migratory corridors**

Maintaining migratory corridors free from obstruction is a critical step in maintaining historical levels of connectivity. Natural rates of movement between subpopulations should not be substantially altered by human actions (McElhany et al. 2000). Barriers, or even partial barriers, change movement patterns and alter dispersal rates (Anderson 2009), which can potentially affect the long term persistence of a population. For Great Basin redband trout, irrigation structures, such as push up dams and irrigation weirs, are common impediments to migration. In addition, poor water quality, unscreened diversions and poorly constructed road culverts also impact movement patterns. Ideally this conservation plan could directly assess the impact of barriers on the migratory behavior of redband trout. Unfortunately the number and location of many impediments to passage are undocumented largely due to lack of access to private property. Thus, a representative measure is employed where the distance of current migratory corridors is compared to the historical distance. The longest continuous stream segment uninterrupted by a known barrier within the entire basin is the unit of comparison and serves to represent connectivity within the population boundary. Populations in which the difference between current and historical corridors is greater than 50% are considered at high risk of being non-viable. It is important to note this metric is based on known barriers. Effects of suspected or unidentified (e.g. undocumented irrigation dams or poor water quality) barriers are listed as a research need.

**Table A1-7 Metric - Percent of current greatest continuous stream distance (i.e. w/o barriers) relative to that distance historically.**

| % of stream | Risk | Score |
|---|---|---|
| > 90% | Very Low | 5 |
| 75-89 % | Low | 4 |
| 50-74 % | Moderate | 3 |
| <50% | High | 1 |

Current and historical distribution, as defined previously (habitat availability metric), served as the basis for this criterion. Barriers included in this assessment were those identified in ODFW's Natural Resource Information Management Program (NRIMP) barriers dataset (ODFW 2011). This dataset describes the location, barrier type (i.e. dam, culvert, and weir) and status (passable, partial, blocked and unknown). All barriers except those classified as passable were considered to have an effect on the migratory behavior of redband trout. Data provided by Oregon Water Resources Department (OWRD) served as supplementary information. These data describe surface water diversion points as determined by water right certificates. In many cases they are undescribed and unverified. In instances where OWRD identified barriers that were directly relevant to this analysis, verification was provided by ODFW field staff.

**Potential for Migratory Behavior**

Life history type potentially affects dispersal rates. Populations that express a larger migratory life history are more likely to move between suitable patches than populations that contain only small resident fish (<200 mm). Populations that have access to large water bodies capable of fostering the growth of large fish (>250mm) have a higher potential of expressing a migratory life history. These habitats are primarily lakes and large rivers (≥ $4^{th}$ order). Maintaining these habitats in places where they were historically present preserves the potential for retaining the historical spatial structure of a population. Populations are rated on the availability of suitable rearing habitat. The intent of this metric is simply to evaluate if habitat is available to foster a migratory life history. In some instances habitat may be available but is not usable 100% of the year, every year, or is inhospitable (e.g. occupied by carp). In cases where the quality of these habitats is compromised, risk to these populations is upgraded until habitat improvements create more consistently hospitable conditions. Human created lakes and impoundments are not considered as potential habitats for this evaluation.

**Table A1-8 Metric – Availability of potential migratory adult rearing habitat**

| Availability | Risk | Score |
|---|---|---|
| Available | Very Low | 5 |
| Available, but not habitable or assessable year around | Moderate | 3 |
| Not Available | High | 1 |

The evaluation of this metric is largely based on professional judgment. Rationale for each population is detailed in the results.

<u>Spatial Structure Scoring –</u>

A mean score is calculated for each component of the spatial structure criterion, habitat availability (quantity, quality and configuration) and connectivity (barriers and migratory habitat). Given spatial structure is maintained by both components, and without either component spatial structure may be compromised, the lowest (highest risk) of the two mean scores becomes the overall score for spatial structure.

Diversity

The degree of genotypic and phenotypic diversity can have a profound effect on population persistence and viability in the face of environmental change. A population with a highly diverse array of genotypes has a large capacity to respond to environmental variability which in turn buffers the population against short term spatial and temporal changes in conditions. A highly diverse population can also exploit a wide variety of environmental and habitat conditions (McElhany et al. 2000). Ultimately, naturally diverse populations may have more stable dynamics, and hence be more viable in changing environments than less diverse populations (Rieman and Dunham 2000). Incorporating a diversity criterion into an assessment of viability helps ensure the preservation of the underlying genetic resources necessary for a population to fully exploit existing ecological opportunities, adapt to future environmental changes, or simply maintain a sustainable status (WLCTRT 2006).

The goal of the diversity metrics is to identify populations where the significant loss of diversity may jeopardize long term viability. This conservation plan uses two metrics to assess diversity, the presence of multiple life history types, and an indirect measure of ecological diversity. The intent is that the direct measure confirms a substantial degree of diversity, and that the indirect ecological measure will be representative of a finer examination when data regarding life history types are unavailable or uncertain.

*Phenotypic diversity – number of life history types*

**Objective –** Maintain phenotypic expression by maintaining known attributes of life history types

For Great Basin redband trout fine details describing the full spectrum of life history variation are unknown. In most populations data specific to phenotypic traits (e.g. spawn timing and age structure) have yet to be collected. In fact, in most populations just the identification of simply a migratory or resident life history is the extent to which life history variation can be described. Therefore the application of this metric reflects the level of resolution to which biologists can describe life history strategies expressed by a population. Thus this metric can only provide two risk categories. When more detailed life history data become available, then additional risk categories will be incorporated.

**Table A1-9 Metric – Life history diversity**

| Life history | Risk | Score |
|---|---|---|
| Multiple Life Histories | Very Low | 5 |
| Resident Only | Moderate | 3 |

Life history studies are rarely available for Great Basin redband trout. This plan assumes every population expresses a resident life history strategy at a minimum. The presence of a migratory component may be indicated by relatively large individuals (> 250 mm) or evidence of significant movement between spawning and adult rearing areas within the past 6 – 7 years (2 generations). For populations where life history information is unknown, the classification of the number of life history types expressed by a population is based on professional judgment.

*Ecological Diversity*

**Objective** – Maintain phenotypic expression by maintaining occupancy in a natural variety of available habitat types where a diversity of spatially-mediated processes occurs.

Diversity within a population is closely related to habitat diversity; where salmonid populations exhibit local adaptation to specific habitats they occupy (Crossin et al. 2004). As a result variation in habitat types promotes the expression of a variety of phenotypes (Hendry et al 1998, Waples et al. 2001). Therefore, it follows, the greater the variation among available habitats, then the higher the probability for phenotypic and genotypic variation within a population (Neville et al. 2009).

This assessment relies on elevation bands to identify different habitat types encountered within the distribution of each population (sensu WLCTRT 2006). Habitats within various elevation categories are generally distinguished by stream order, gradient, and thermal regimes, all factors which influence local adaptation. To quantify reductions in diversity, comparisons are made between current and historical distribution of fishes within each elevation band. The metric calculates the average absolute change in proportion between current and historical distribution within each category.

**Table A1-10 Metric – Average cumulative % change in occupancy across elevation bands.**

| % Change | Risk | Score |
|---|---|---|
| < 5% | Very Low | 5 |
| 6 - 10% | Low | 4 |
| 11 - 20% | Moderate | 3 |
| > 20% | High | 1 |

For this metric current distribution equates to the potential distribution as defined by the NFIP sample frame. Historical distribution is as previously defined for the habitat availability metric. The stream distance of current and historical distribution within 50m elevation categories was calculated using a GIS. The cumulative percent change was then calculated as follows:

$$\Delta ED = \frac{\sum_i |P_{Hi} - P_{Ci}|}{n}$$

Where n = the number of elevation categories, i, $P_{Hi}$ = the proportion of the historical distribution in elevation category i and $P_{Ci}$ = the proportion of the current distribution in elevation category *i* (WLCTRT 2006). Defining current distribution as the potential distribution could misrepresent the degree of change. In basins where the currently occupied stream reaches are significantly different from the potential distribution the change in ecological diversity will be underestimated.

Diversity Scoring –

The final diversity score is calculated as the mean of the two metrics. This approach equally weights the two metrics and speaks to the significantly different aspects of diversity that each evaluates.

Viability

The scores for the four viability parameters are combined to generate an overall rating of risk for each population. The mean score is calculated for abundance and productivity (A/P), as is the mean for spatial structure and diversity (SS/D) scores. The mean scores are then rated according to the matrix below. Given that spatial structure and diversity are likely equal to, if not more, important than abundance and productivity as they relate to redband trout population viability, the combined A/P and SS/D scores are weighted equally.

**Table A1-11**

| A/P (mean of the two scores) | Spatial Structure & Diversity (mean of the two scores) | | | | |
|---|---|---|---|---|---|
| | Risk | Very Low (5) | Low (4) | Moderate (3) | High (1) |
| | Very low (5) | Very Low | Low | Moderate | Moderate |
| | Low (4) | Low | Low | Moderate | High |
| | Moderate (3) | Moderate | Moderate | Moderate | High |
| | High (1) | Moderate | High | High | High |

**Results**

Of the nine redband trout populations in the Malheur Lakes SMU, one was rated as at low risk of not being viable, six at moderate risk, and two at high risk (Table A1-12).
In general, population level abundance was much greater than the threshold estimated to identify populations at high risk of the deleterious effects of small population size. Of the seven populations evaluated with rigorous estimates of abundance, all were estimated to exceed the 2,500 fish >100mm. Two populations scored poorly relative to abundance; Prater and Cow (Table A1-12). Data pertinent to these populations was very limited, preventing a rigorous population estimate. The poor score primarily is due to a lack of recent observations of fish or of fish at moderate densities.

Length frequency analysis suggests productivity is likely adequate to maintain net replacement in seven of the nine populations. These populations contained a relatively high proportion of juvenile fish indicative of high recruitment levels. The proportion of fish > 200mm was variable among populations and rarely exceeded 10%. Two populations showed indications of poor productivity, Prater and Cow (Table A-12). Again, the lack of appropriate data plays a significant role in the assessment results for these populations.

The population assessment shows the spatial structure of many populations is highly compromised. Only the Blitzen was rated as maintaining good spatial structure and only Poison was rated as fair (Table A1-12). The remaining seven populations are scored poorly for the metric. Generally, degraded habitat, passage barriers, and loss of historical habitat have negatively impacted the potential of populations maintaining their historical metapopulation structure.

Overall, the viability metrics reflect most populations have likely maintained adequate levels of diversity. Prater Creek, the only population for which diversity was scored as poor showed a significant loss of habitat that resulted in a relatively substantial decrease in ecological diversity. Life history diversity is also limited in most populations, where all populations except the Blitzen are assumed to contain only a stream resident form.

**Table A1-11--Population assessment results for Malheur Lakes redband trout SMU.**

| SMU | Population | Abundance | Productivity | Spatial Structure | Diversity | Viability Risk |
|---|---|---|---|---|---|---|
| Malheur Lakes | **Silver** | Good | Good | Poor | Good | Moderate |
| Malheur Lakes | **Silvies** | Good | Good | Poor | Good | Moderate |
| Malheur Lakes | **Poison** | Good | Good | Fair | Good | Moderate |

| | | | | | | |
|---|---|---|---|---|---|---|
| Malheur Lakes | **Prater** | Poor | Poor | Poor | Poor | High |
| Malheur Lakes | **Rattlesnake** | Good | Good | Poor | Good | Moderate |
| Malheur Lakes | **Coffeepot** | Fair | Fair | Poor | Good | Moderate |
| Malheur Lakes | **Cow** | Poor | Poor | Poor | Good | High |
| Malheur Lakes | **Riddle** | Good | Fair | Fair | Good | Moderate |
| Malheur Lakes | **Blitzen** | Good | Good | Good | Good | Low |

<u>Silver Creek</u>

The Silver Creek basin drains the southernmost extent of Oregon's Blue Mountains and historically flowed into the highly alkaline Harney Lake (Fig.A1-1). The redband trout population that occupies the watershed was rated as at moderate risk of not being viable.

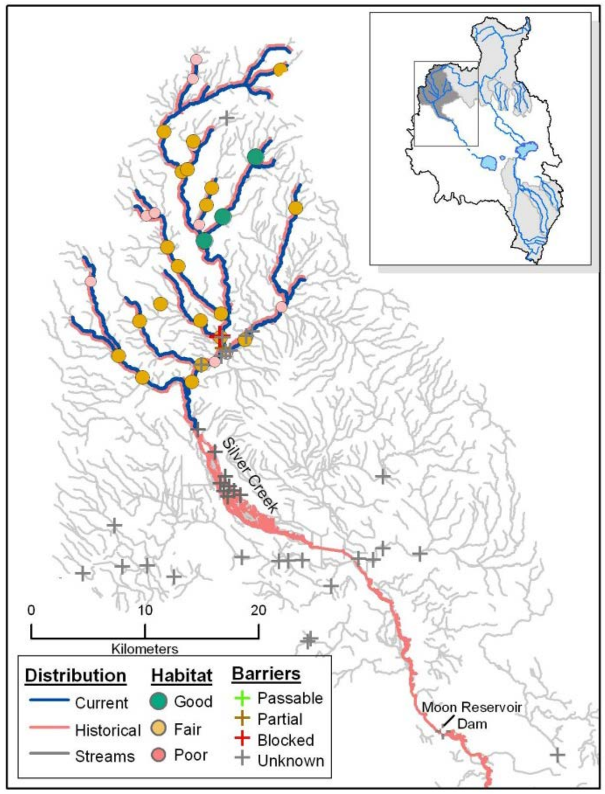


**Figure A1-1. Silver Creek redband trout population**

Metrics of both abundance and productivity were scored high and rated as at low risk. Measures of abundance and average density exceeded the minimum benchmarks of viability (Table A1-12). In 2008 the population was estimated to contain 43,000 fish (-/+ 34%) > 100mm, easily large enough to avoid the deleterious effects of small population size. Indicators of productivity exceed the minimum benchmarks of viability, except for the proportion of large fish (Table A1-12). Of all fish > 100mm collected 6.4% were > 200mm. This low proportion of large adults may be indicative of declines in long term survival, loss of a migratory life history, and potentially a decrease in productivity. It is worth noting that site occupancy and fish density estimates are highly variable in this basin (Miller et al. 2010, http://oregonstate.edu/dept/ODFW/NativeFish/GreatBasinRedband.htm ). While abundance and productivity are considered to be sufficient, continued monitoring of this population is recommended.

The potential of the Silver Creek population to maintain its historical spatial structure was highly compromised, primarily due to factors associated with connectivity. Only 39% (42.6 Km) of the longest historical migratory corridor (109 Km) was currently accessible (Table A1-12). Irrigation diversions (permanent and temporary) in the lower basin (OWRD, unpublished data) (Fig 1), Silver Creek Dam and a dam at Moon Reservoir reduce flow and act as barriers to migration. Trout are unable to access Harney Lake and larger stream reaches that were once suitable for supporting a migratory life history (Bowers et al. 1999). This lack of habitat suitable for rearing large migratory fish further reduces the potential for within-population connectivity. In addition, spatial structure is altered by moderately reduced habitat availability. Current distribution is just 57% (186 km) of historical distribution (302 km) and habitat quality was considered to be degraded. The scoring of habitat quality borders between high and moderate risk. Given the negative bias of the modified HabRate model and that 10% of the sites were rated as good quality this assessment downgraded the risk level of the habitat quality metric to moderate.

Diversity measures for the Silver Creek population suggest diversity has declined slightly in the past 200 years. The diversity parameter was rated as at low risk, though borders it borders on moderate (Table A1-12). Life history diversity appears to be limited. In the absence of studies specific to movement and other life history traits the population was assumed to express just a stream – resident life history type. Whether a migratory life history is periodically expressed as conditions allow is unknown. The analysis of change in ecological diversity show a small change in the distribution of habitats where the loss of distribution in the lower reaches may have altered phenotypic and genetic variation within the population.

**Table A1-12--Viability metrics, scores and rating for the Silver Creek redband trout population.**

| Parameter | Value | Scoring | | | Viability Rating |
|---|---|---|---|---|---|
| **Abundance** | | | | | Moderate Risk |
| Estimate | 43,219 | | | 5 Very Low | |
| Lower 95% CI | 28,508 | | | | |
| Km of distribution | 186 | | | | |
| Fish/Km | 270 | | | | |
| n (sites) | 25 | | | | |
| **Productivity** | | | | | |
| %<100mm | 32.0 | 5 | | 4 Low | |
| %>200 mm | 6.4 | -1 | | | |
| n (fish) | 275 | | | | |
| n (sites) | 28 | | | | |
| **Spatial Structure** | | | | | |
| *Habitat Availability* | | | 3.7 | 1 High | |
| Habitat Quantity: % historical occupied | 57.3 | 3 | | | |
| Habitat Quality (n=33): % Good | 9.1 | 3 | | | |
| % Fair | 60.6 | | | | |
| % Poor | 30.3 | | | | |
| Configuration: Stream order | 5 | 5 | | | |
| No. of tributary junctions | >5 | | | | |
| *Connectivity* | | | 1 | | |
| % historical corridors accessible | 39.1 | 1 | | | |
| Rearing habitat available | No | 1 | | | |
| **Diversity** | | | | | |
| No. of life history types | 1 | 3 | | 3.5 Low | |
| Change in ecological diversity | 5.6 | 4 | | | |

Silvies River

The Silvies population was rated as at a moderate risk of not being viable. Although abundance, productivity and diversity measures were rated as at low risk, metrics associated with spatial structure were rated as at high risk.

Metrics describing both abundance and productivity were scored high and rated as at low risk. Measures of density and total abundance indicate the Silvies population was large enough to avoid the deleterious effects commonly associated with small population size (Table A1-13). Analysis of productivity revealed 44% of the fish sampled 2007-2010 were juveniles (<100mm), a proportion exceeding the benchmark for populations at low risk. This large proportion of juveniles suggested potential for high recruitment rates. However, the proportion of large fish was lower than the benchmark for populations at high risk and served as a note of caution. Of fish > 100mm the percentage > 200mm was 4.7%, suggesting possible declines in habitat conditions, a decrease in long-term survival, and an overall decrease in intrinsic productivity.

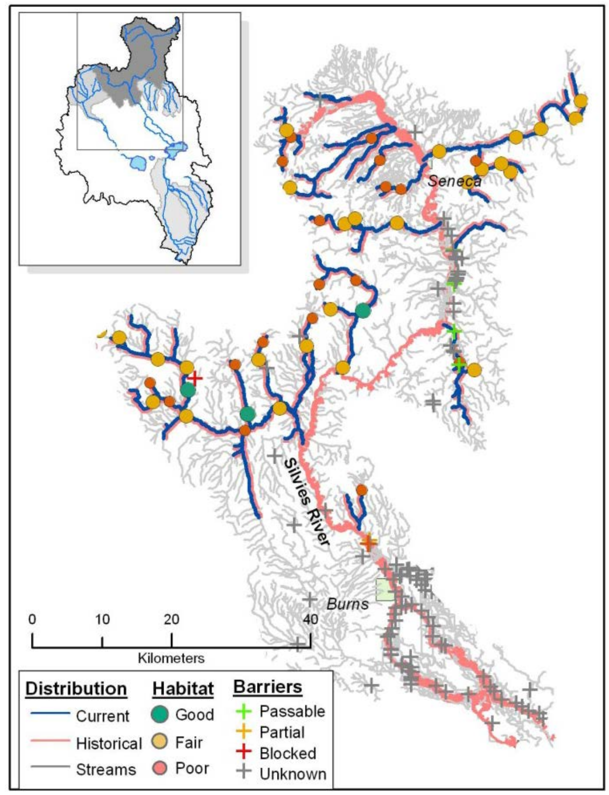


Figure A1-2. Silvies River redband trout population

This population assessment shows the spatial structure of the Silvies population was highly compromised. Scores reflecting habitat quality and quantity were lower than what was defined for a viable population (Table A1-13). The historical distribution was estimated to be 784 Km, of which only 39% (468 km) are currently occupied. The current distribution is highly fragmented where year around occupancy primarily occurs in isolated tributary streams (Fig. A1-2). It is important to note that current distribution was likely underestimated in this analysis. The mainstem river is not included in the NFIP sample frame, the basis for current distribution, since it cannot be sampled by backpack electrofishers. In addition, current data describing the year around occupancy for the mainstem do not exist. In 1984-5 Hosford and Pribyl (1991) documented redband trout at three upper reaches sites of the mainstem river (between Seneca and Myrtle Creek). Sampling during 1999-2000 documented few, if any, redband trout in the mainstem river habitats (Ray Perkins, ODFW biologist, Ontario -- personal communication). Further investigation is required to determine redband trout use of the mainstem Silvies River.

Scores for habitat quality within the current distribution reflect degraded conditions; 40% of the in-stream habitat was rated as poor quality (Table A1-13). The habitat quality scores do not capture current conditions of the mainstem Silvies River. Poor water quality and the presence of non-native fish are thought to create an inhospitable environment for redband trout of all life stages in the summer months (Ray Perkins – ODFW (retired), personal communication). Non-native fish species found in the mainstem Silvies River include: hatchery origin rainbow trout, brook trout, smallmouth bass, largemouth bass, bluegill, pumpkinseed, white crappie, yellow perch, brown bullhead and common carp (Hosford and Pribyl 1991).`

In addition to reduced habitat availability, potential for within population connectivity was moderately reduced. The lower mainstem Silvies River contains numerous diversion dams of which passage has not been documented (Fig A1-2). The longest uninterrupted stream distance historically was 250 km. Five Mile Dam, a permanent barrier, and Parker Dam, a significant seasonal barrier, reduce this distance by approximately 35%. However, given the poor water quality conditions, the non-native fish community in the mainstem river, and the numerous seasonal impassable irrigation dams on both the mainstem and all of the major tributaries this number likely underestimates the degree to which migratory corridors and adult rearing habitats are no longer accessible (Bowers et al. 1999). In addition, Bridge, House, and Mountain creeks are intercepted by an irrigation canal; fish in these streams have no access to and from the mainstem river (Bowers et al 1999).

It is unknown if habitats exist that are suitable for supporting migratory fish. Presence of these habitats may increase the potential for movement and connectivity. Given the numerous diversions and conditions in Silvies River, this assessment assumes that if redband trout can move into Malheur Lake and the lower mainstem river, they cannot return. The upper mainstem river habitats are considered only periodically suitable for fostering a migratory life history. These factors associated with potential intra-population connectivity undoubtedly affect the historical spatial structure template once present in the Silvies River population.

Indicators of population diversity in Silvies River suggest diversity was less than what it was pre-settlement (Table A1-13). The diversity parameter was rated as at low risk though was border line moderate due to limited life history diversity. The population is assumed to only express a resident life history. Evidence does not exist to suggest a migratory life history (fluvial or adfluvial) is currently expressed, though movement and life history have not been specifically studied. The examination of ecological diversity shows small changes in the relative distribution of habitats at low elevation indicative of only a slight loss of genotypic and phenotypic diversity.

**Table A1-13.--Viability metrics, scores and rating for the Silvies Creek redband trout population.**

| Parameter | Value | Scoring | | | Viability Rating |
|---|---|---|---|---|---|
| **Abundance** | | | | | Moderate Risk |
| Estimate | 117,678 | | | 5<br>Very Low | |
| Lower 95% CI | 68,527 | | | | |
| Km of distribution | 468 | | | | |
| Fish/Km | 260 | | | | |
| n (sites) | 23 | | | | |
| **Productivity** | | | | | |
| %<100mm | 44 | 5 | | 4<br>Low | |
| %>200 mm | 4.7 | -1 | | | |
| n (fish) | 1021 | | | | |
| n (sites) | 46 | | | | |
| **Spatial Structure** | | | | | |
| *Habitat Availability* | | | 2.3 | 2.3<br>High | |
| Habitat Quantity | | | | | |
| % historical occupied | 39 | 1 | | | |
| Habitat Quality (n=47) | | 1 | | | |
| % Good | 6.4 | | | | |
| % Fair | 53.2 | | | | |
| % Poor | 40.4 | | | | |
| Configuration | | 5 | | | |
| Stream order | 6 | | | | |
| No. of tributary junctions | >5 | | | | |
| *Connectivity* | | | 3 | | |
| % historical corridors accessible | 65 | 3 | | | |
| Rearing habitat available | Seasonally | 3 | | | |
| **Diversity** | | | | | |
| No. of life history types | 1 | 3 | | 3.5<br>Low | |
| Change in ecological diversity | 3.4 | 4 | | | |

Poison Creek

The redband trout population residing in the Poison Creek drainage was rated as at a moderate risk of not being viable (Table A1-14). Evaluation of the VSP parameters indicates abundance, productivity and diversity of this population were above that necessary for a viable population, whereas alterations in spatial structure were limiting (Table A1-14). Estimates of total abundance exceeded the suggested benchmark of 2,500 fish >100mm and the average density was twice that recommended by the metric. Indicators of productivity for Poison Creek redband trout reflect potential for high rates of recruitment, where 44% of the fish captured were less than 100mm. The proportion of fish > 100mm that are > 200mm was only 1.5%. This low proportion may be indicative of possible declines in habitat conditions, the absence of a migratory life history type, and an overall decrease in intrinsic productivity. A significant portion of Poison Creek upstream of Devine Canyon was not surveyed due to lack of access provided by private landowners (Fig A1-3). The absence of surveys in this reach decreased confidence in the assessment of abundance and productivity.

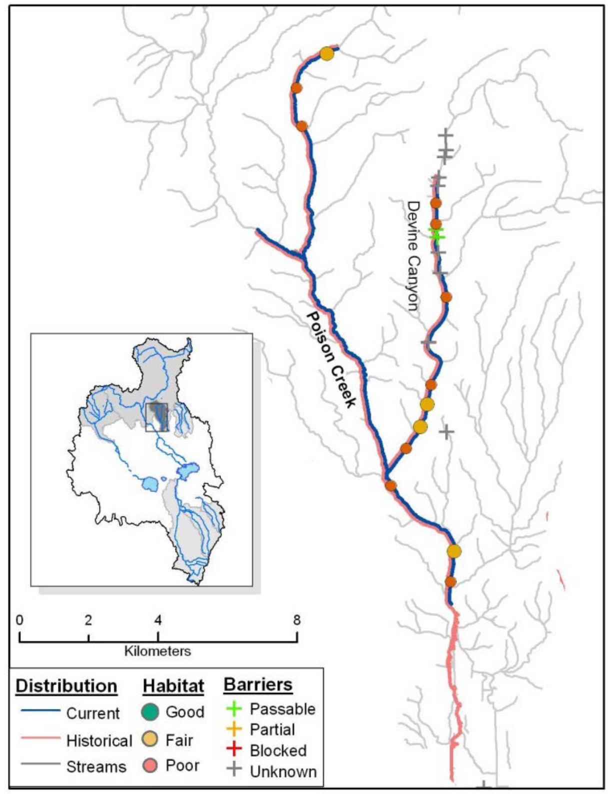

Figure A1-3 Poison Creek redband trout population

The moderate rating for the Poison Creek population was primarily due to the low scores for spatial structure, specifically habitat quality (Table A1-14). Of the 13 sites where habitat was evaluated 70% were rated as poor quality and 30% were fair quality. None were rated as in good condition. State Highway 395 follows the creek through Devine Canyon and likely impacts habitat quality. Similar to the abundance and productivity metrics, the lack of surveys on a large portion of Poison Creek decreased confidence of the habitat quality metric. Habitat quantity was rated as at low risk. Current distribution occupied 84% (30 km) of the 36 km considered as historical distribution, most of the habitat loss occurs in the lower system (Fig A1-3). The natural configuration of the watershed was rated as at moderate risk due to the lack of substantial bifurcation and inherent small size. The Poison Creek drainage contains just two streams, limiting habitat available to support multiple subpopulations and increasing risk to catastrophic stochastic events. The analysis of the connectivity criterion shows that the 100% of the historical migratory corridors were currently accessible. However, Devine Canyon contains 10 culverts under Highway 395 for which the condition and passage status of many were not documented. Further examination may reveal passage barriers under certain flow conditions. Within population connectivity may also be hampered by a lack of habitat capable of fostering migratory fish.

Diversity criteria for the Poison Creek population suggest diversity has declined only slightly in the past 200 years. In the absence of life history studies, life history diversity appears to be low. The population was assumed to express only a stream-resident life history based on the absence of habitat capable of supporting a migratory life history and few individuals over 200mm. Change in ecological diversity was minimal.

**Table A1-14--Viability metrics, scores and rating for the Poison Creek redband trout population.**

| Parameter | Value | Scoring | | | Viability Rating |
|---|---|---|---|---|---|
| **Abundance** | | | | | Moderate Risk |
| Estimate | 15,671 | | | 5<br>Very Low | |
| Lower 95% CI | 7,779 | | | | |
| Km of distribution | 31 | | | | |
| Fish/Km | 507 | | | | |
| n (sites) | 12 | | | | |
| **Productivity** | | | | | |
| %<100mm | 43.6 | 5 | | 4<br>Low | |
| %>200 mm | 1.5 | -1 | | | |
| n (fish) | 241 | | | | |
| n (sites) | 18 | | | | |
| **Spatial Structure** | | | | | |
| *Habitat Availability* | | | 2.7 | 2.7<br>Moderate | |
| Habitat Quantity | | | | | |
| % historical occupied | 83.8 | 4 | | | |
| Habitat Quality (n=13) | | 1 | | | |
| % Good | 0.0 | | | | |
| % Fair | 30.8 | | | | |
| % Poor | 69.2 | | | | |
| Configuration | | 3 | | | |
| Stream order | 3 | | | | |
| No. of tributary junctions | 1 | | | | |
| *Connectivity* | | | 3 | | |
| % historical corridors accessible | 100 | 5 | | | |
| Rearing habitat available | No | 1 | | | |
| **Diversity** | | | | | |
| No. of life history types | 1 | 3 | | 4<br>Low | |
| Change in ecological diversity | 3.8 | 5 | | | |

Prater Creek

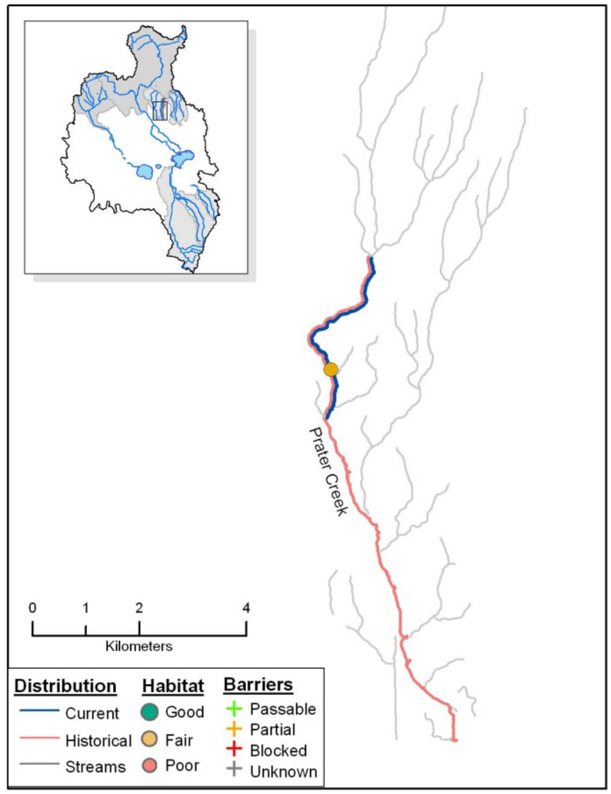


Figure A1-4. Prater Creek redband trout population.

Very little empirical data was available for the redband trout population in Prater Creek. The population was sampled in 1994 and 2008, one site in each year. Both sampling efforts did not detect fish. Other empirical data did not exist for this population. The lack of information was primarily due to the agency's inability to access the private property on which this population resides. Prater Creek was identified as a population in Bowers et al. (1999), suggesting that at one point redband trout were observed in Prater Creek. All metrics associated with the assessment of this population were based on very little or no data and confidence is very limited.

The Prater Creek population was rated as at a high risk of not being viable. All parameters were scored extremely low. Population abundance was presumed to be extremely low and rated as at high risk. Fish have not been detected since prior to 1994, though sample efforts have been minimal. Given current distribution was estimated to extend just four kilometers, fish density in reaches on private property would have to exceed 625 fish/km in order to surpass the 2500 fish >100mm abundance benchmark. Densities of this magnitude were highly unlikely. Productivity was also rated as at high risk given the lack of data and observations of fish.

Both spatial structure and diversity were scored low and rated as at high risk (Table A1-15). Metrics describing habitat availability and connectivity indicate the potential of the population to maintain its historical spatial structure is quite low. The population was assumed to currently occupy only 35% of its historical distribution (Fig A1-4). Habitat quality within current distribution was rated as fair, however confidence in this assessment was minimal given the small sample size (n=1) (Table A1-15). The linear configuration of the current distribution further increases risk to the population. Although no known permanent barriers exist within current and historical migratory corridors, habitat capable of fostering migratory adults does not exist. The inability of the habitat to produce migratory fish decreased the potential for within population connectivity. All indicators suggest population diversity has diminished. The population was assumed to express a single resident life history type. The change in ecological diversity was the greatest of all populations and was associated with significant loss of genotypic and phenotypic diversity.

**Table A1-15--Viability metrics, scores and rating for the Prater Creek redband trout population.**

<table>
<tr><th>Parameter</th><th>Value</th><th colspan="3">Scoring</th><th>Viability Rating</th></tr>
<tr><td colspan="5">Abundance</td><td rowspan="14">High Risk</td></tr>
<tr><td>Estimate<br>Lower 95% CI<br>Km of distribution<br>Fish/Km<br>n (sites)</td><td>-<br>-<br>4<br>-<br>1</td><td colspan="3">1<br>High</td></tr>
<tr><td colspan="5">Productivity</td></tr>
<tr><td>%<100mm<br>%>200 mm<br>n (fish)<br>n (sites)</td><td>-<br>-<br>-<br>1</td><td colspan="2">0<br>-1</td><td>1<br>High</td></tr>
<tr><td colspan="5">Spatial Structure</td></tr>
<tr><td colspan="2">Habitat Availability</td><td></td><td rowspan="4">1.7</td><td rowspan="7">1.7<br>High</td></tr>
<tr><td><u>Habitat Quantity</u><br>% historical occupied</td><td>35.0</td><td>1</td></tr>
<tr><td><u>Habitat Quality (n=1)</u><br>% Good<br>% Fair<br>% Poor</td><td>0.0<br>100<br>0.0</td><td>3</td></tr>
<tr><td><u>Configuration</u><br>Stream order<br>No. of tributary junctions</td><td>-<br>0</td><td>1</td></tr>
<tr><td colspan="2">Connectivity</td><td></td><td rowspan="3">3</td></tr>
<tr><td>% historical corridors accessible</td><td>100</td><td>5</td></tr>
<tr><td>Rearing habitat available</td><td>No</td><td>1</td></tr>
<tr><td colspan="5">Diversity</td></tr>
<tr><td>No. of life history types</td><td>1</td><td colspan="2">3</td><td rowspan="2">2<br>High</td></tr>
<tr><td>Change in ecological diversity</td><td>24.3</td><td colspan="2">1</td><td></td></tr>
</table>

Coffeepot Creek

The redband trout population residing in Coffeepot Creek was rated as at a moderate risk of not being viable. This assessment was primarily based on best professional judgment due to a lack of empirical data. Coffeepot Creek was sampled two times, once in 2001 and 2008. Sampling in 2001 by ODFW Hines district staff failed to produce a density estimate, but the number and size distribution of fish captured indicated a relatively abundant and productive population (ODFW 2005; ODFW, Hines field office, unpublished data). The one sample site visited in 2008 also contained fish at a very high density in a variety of size classes. Even though these data might suggest a highly abundant fish population, the extremely small sample size (n=1) reduces confidence in the assessment and the lack of data puts the population at greater risk. Abundance was rated as at moderate risk of not being viable given the lack of data. Productivity was rated in a similar fashion, where even though the data collected at one sample site indicated the metric should be scored as at low risk (Table A1-16), small sample size justifies upgrading the risk category to moderate. Further population level sampling is required to better assess this population.

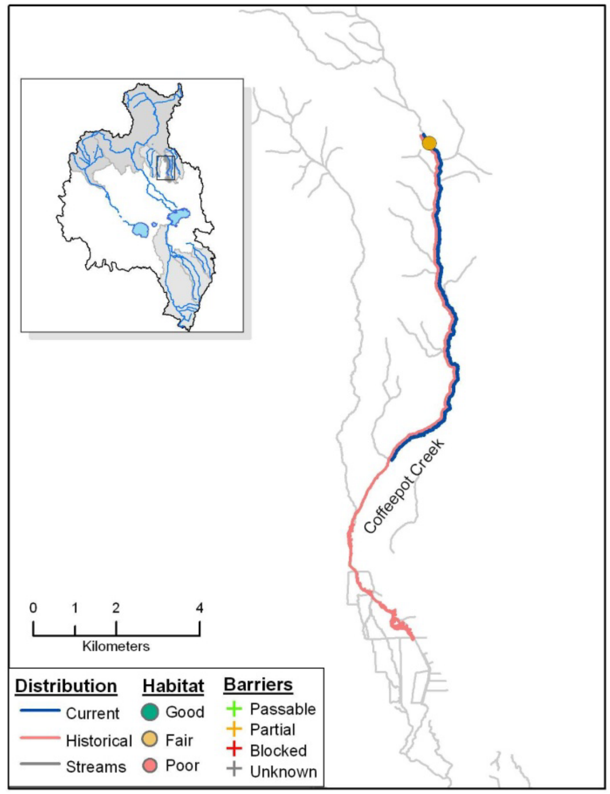


**Figure A1-5. Coffeepot Creek redband trout population.**

As with other populations draining King Mountain, the spatial structure of the Coffeepot population no longer reflects the historical template and was rated as at high risk of not being viable. Risk to the population is highly jeopardized by the linear configuration of the stream system it inhabits. The lack of a dendritic stream network limits opportunities to establish multiple spawning areas or subpopulations and increases the risk due to random stochastic events. The population is presumed to occupy 63% (10 km) of this historical distribution (16 km) (Fig A1-5), however this figure is questionable. The lower 7km identified as current distribution occurs on private property, most of which the agency has not been able to access. As a result, the lower distribution is undescribed. Similarly, the lack of access to the stream channel prevents a reliable assessment of habitat quality. A score of high risk was given for habitat availability until further investigation can determine otherwise. Within population connectivity is compromised by the lack of habitat suitable for rearing migratory fish, minimizing the probability of fish moving throughout the population. No known passage barriers exist in the basin, though the Oregon Water Resources Department (unpublished data) lists seven surface water diversion points in the lower river downstream of current fish distribution, but within historical distribution. The status and condition of these diversions are unknown. Based on these factors intra-population connectivity was rated as at moderate risk.

Current within population diversity is likely less than that present historically. The population was assumed to express a single resident life history type. Evidence was not available to suggest the Coffeepot population also expresses a migratory life history, lowering the diversity score to moderate. The analysis of change in ecological diversity shows there has been a slight change in the distribution of habitats since pre-settlement where a majority of the distribution has switched from lower to mid-elevations. This change in ecological diversity is likely a reflection of a similar degree of change in genotypic and phenotypic diversity. Population diversity was rated as at moderate risk.

**Table A1-16--Viability metrics, scores and rating for the Coffeepot Creek redband trout population.**

| Parameter | Value | Scoring | | | Viability Rating |
|---|---|---|---|---|---|
| **Abundance** | | | | | Moderate Risk |
| Estimate | - | | | 3 Moderate | |
| Lower 95% CI | - | | | | |
| Km of distribution | 10 | | | | |
| Fish/Km | - | | | | |
| n (sites) | 1 | | | | |
| **Productivity** | | | | | |
| %<100mm | 72.2 | - | | 3 Moderate | |
| %>200 mm | 0 | - | | | |
| n (fish) | 33 | | | | |
| n (sites) | 1 | | | | |
| **Spatial Structure** | | | | | |
| *Habitat Availability* | | | 2 | 2.0 High | |
| Habitat Quantity: % historical occupied | 62.5 | 3 | | | |
| Habitat Quality (n=1): % Good, % Fair, % Poor | 100 | 3 | | | |
| Configuration: Stream order | - | 1 | | | |
| No. of tributary junctions | 1 | | | | |
| *Connectivity* | | | 3 | | |
| % historical corridors accessible | 100 | 5 | | | |
| Rearing habitat available | No | 1 | | | |
| **Diversity** | | | | | |
| No. of life history types | 1 | 3 | | 3.5 Moderate | |
| Change in ecological diversity | 9.8% | 4 | | | |

Rattlesnake Creek

The redband trout population inhabiting Rattlesnake Creek was rated as at a moderate risk of not being viable. While abundance and productivity metrics were indicative of a viable population, measures of spatial structure, and to some degree diversity, appear to be highly compromised. Population abundance was estimated to be above the benchmark of a viable population (Table A1-17). In fact, the estimated average density, 547 fish / km, was among the highest of all northern basin populations, though the relatively small sample size (n=6) provides low confidence. Scores representative of productivity show a high proportion of juvenile fish (52%) suggesting high potential for recruitment. However, the proportion of fish > 100mm that exceeded 200mm was 3% (Table A1-18). The low proportion of large fish may suggest a decrease in intrinsic productivity, long term survival and environmental conditions. Overall productivity was rated as at low risk.

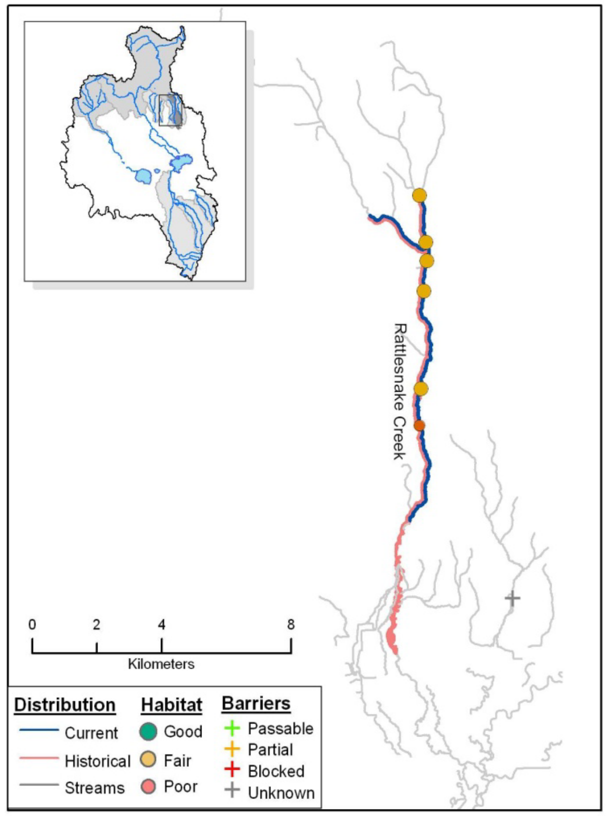

**Figure A1-6. Rattlesnake Creek redband trout population.**

The spatial structure of the Rattlesnake Creek population appears to be highly compromised. Of greatest risk to the population was the nearly linear configuration of the stream system it occupies which offers few opportunities to develop multiple spawning areas and is highly vulnerable to risks associated with stochastic events. Habitat quantity and quality were rated as at moderate risk. Analyses indicate possible degradation of the spatial structure over the past 200 years (Table A1-17). The population currently occupies 59% (11 km) of its historical habitat (20 km) and 83% of the current habitat was rated as in fair condition (Fig A1-6). None of the six sites surveyed in 2007-2010 were rated as good quality. Potential for within population connectivity was reduced by the lack of habitat suitable for rearing migratory individuals, thus decreasing the probability of fish moving throughout the basin. No known passage barriers exist in the basin. Given these factors intra-population connectivity was considered to be at moderate risk.

Analyses of the diversity criteria suggest redband trout in the Rattlesnake population may be less diverse than historically (Table A1-17). The population was assumed to contain only stream resident fish. No evidence was found to suggest the Rattlesnake population expresses a migratory life history type, though studies specifically designed to describe life history have not been conducted. The analysis of change in ecological diversity reflects only a slight change in the distribution of habitats since pre-settlement. The proportion of habitat in the lower reaches has been slightly reduced potentially resulting in a loss of genotypic and phenotypic diversity.

**Table A1-17.** Viability metrics, scores and rating for the Rattlesnake Creek redband trout population.

| Parameter | Value | Scoring | | | Viability Rating |
|---|---|---|---|---|---|
| **Abundance** | | | | | Moderate Risk |
| Estimate | 7,581 | | | 5 Very Low | |
| Lower 95% CI | 3,698 | | | | |
| Km of distribution | 4 | | | | |
| Fish/Km | 547 | | | | |
| n (sites) | 6 | | | | |
| **Productivity** | | | | | |
| %<100mm | 51.5 | 5 | | 4 Low | |
| %>200 mm | 3 | -1 | | | |
| n (fish) | 136 | | | | |
| n (sites) | 6 | | | | |
| **Spatial Structure** | | | | | |
| *Habitat Availability* | | | 2.3 | 2.3 High | |
| <u>Habitat Quantity</u> | | | | | |
| % historical occupied | 58.8 | 3 | | | |
| <u>Habitat Quality (n=6)</u> | | 3 | | | |
| % Good | 0.0 | | | | |
| % Fair | 83.3 | | | | |
| % Poor | 16.7 | | | | |
| <u>Configuration</u> | | 1 | | | |
| Stream order | 2 | | | | |
| No. of tributary junctions | 1 | | | | |
| *Connectivity* | | | 3 | | |
| % historical corridors accessible | 100 | 5 | | | |
| Rearing habitat available | No | 1 | | | |
| **Diversity** | | | | | |
| No. of life history types | 1 | 3 | | 3.5 Moderate | |
| Change in ecological diversity | 7% | 4 | | | |

Cow Creek

The Cow Creek population was rated as at high risk of being not viable. All indicators suggest the abundance and productivity of redband trout in this population are extremely low (Table A1-18). Since 2007, seven sites were successfully sampled in the upper third of the basin and only one fish was found. Six additional samples sites were dry. The one fish captured was 193mm which provides no evidence of recent reproduction. Given these observations both abundance and productivity were rated as at high risk.

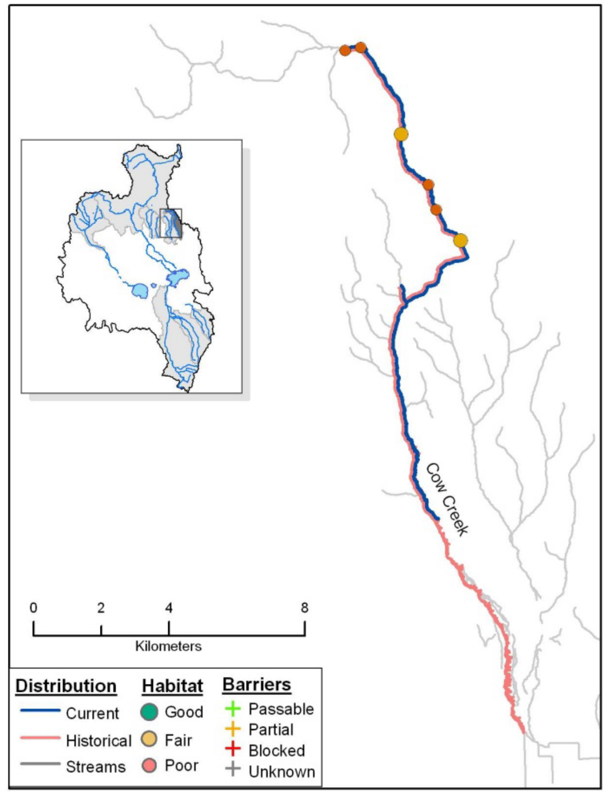

Figure A1-2. Cow Creek redband trout population.

Spatial structure of the Cow Creek population was also rated as at high risk due to low scores for habitat availability (Table A1-18). Based on recent sampling the redband trout population is estimated to occupy only 14% (4 km) of the presumed historical distribution (28Km) (Fig A1-7). Of the occupied habitat, 66% was rated as poor quality. Furthermore, the population is highly jeopardized by the linear configuration of the stream system it inhabits. The lack of a dendritic stream network limits opportunities to establish multiple spawning areas or subpopulations and increases the risk due to stochastic events. Potential within population connectivity is compromised by the lack of access to habitat suitable for rearing large migratory adults, thus decreasing the probability of fish moving throughout the stream. No known passage barriers exist in the basin, though the Oregon Water Resources Department (unpublished data) lists 11 surface water diversion points in the lower river downstream of fish distribution. The type, status, and condition of these diversions were unknown.

No evidence has been found to suggest the Cow Creek population expresses a diversity of life history types. The population was assumed to express only a stream-resident life history type. The analysis of change in ecological diversity shows there has been a slight change in the distribution of habitats since pre-settlement where a majority of the distribution has switched from lower elevations to mid-elevations. This change in distribution likely reflects a similar change in genotypic and phenotypic diversity.

**Table A1-18--Viability metrics, scores and rating for the Cow Creek redband trout population.**

| Parameter | Value | Scoring | | | Viability Rating |
|---|---|---|---|---|---|
| **Abundance** | | | | | High Risk |
| Estimate | 59 | | | 1<br>High | |
| Lower 95% CI | 1 | | | | |
| Km of distribution | 20 | | | | |
| Fish/Km | 4.5 | | | | |
| n (sites) | 5 | | | | |
| **Productivity** | | | | | |
| %<100mm | 0 | 1 | | 0<br>High | |
| %>200 mm | 0 | -1 | | | |
| n (fish) | 1 | | | | |
| n (sites) | 1 | | | | |
| **Spatial Structure** | | | | | |
| *Habitat Availability* | | | 1 | 1<br>High | |
| Habitat Quantity: % historical occupied | 14 | 1 | | | |
| Habitat Quality (n=6) | | 1 | | | |
| % Good | 0.0 | | | | |
| % Fair | 33.3 | | | | |
| % Poor | 66.7 | | | | |
| Configuration | | 1 | | | |
| Stream order | - | | | | |
| No. of tributary junctions | 0 | | | | |
| *Connectivity* | | | 3 | | |
| % historical corridors accessible | 100 | 5 | | | |
| Rearing habitat available | No | 1 | | | |
| **Diversity** | | | | | |
| No. of life history types | 1 | 3 | | 3.5<br>Moderate | |
| Change in ecological diversity | 6.1% | 4 | | | |

Riddle

The redband trout population residing in the Riddle Creek watershed was assessed as at moderate risk of not being viable. Abundance and diversity metrics were scored high and rated as at low risk whereas low scores for productivity and spatial structure provided a cause of concern (Table A1-19).

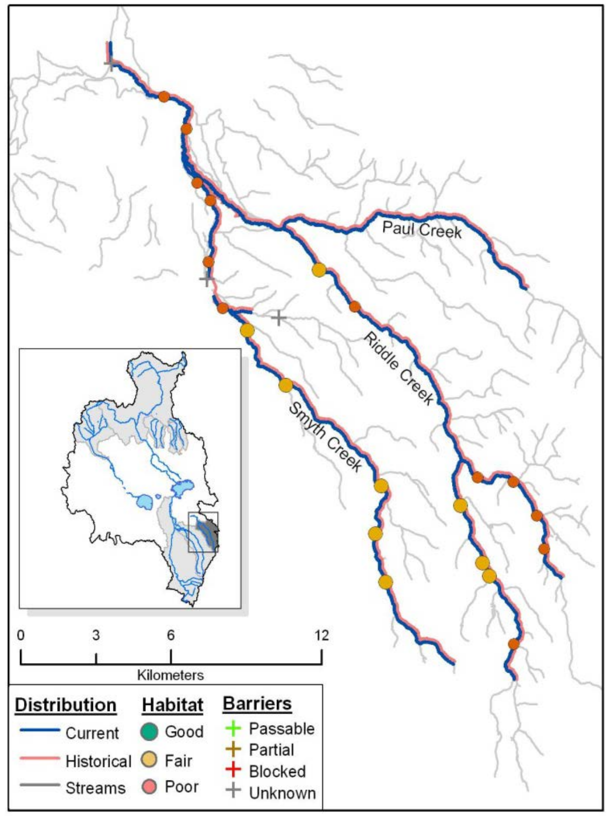


Figure A1-3. Riddle Creek redband trout population.

Based on data collected at 18 sites in 2008, measures of total fish abundance and average fish density were estimated to be well above the minimum benchmarks (Table A1-19) which suggests the Riddle Creek population was not subject to the deleterious processes that affect small populations. The abundance metric was rated at very low risk of not being viable.

Measures of productivity reflect a moderately productive population (Table A1-19). The proportion of fish <100mm, 17%, while not alarmingly low, may indicate low levels of recruitment and suggest the population is not consistently able to replace itself. Also the population contains a modest proportion of 100+mm fish >200mm, 10%. These larger individuals potentially increase the productivity given their higher fecundity and ability to dig deeper, more scour resistant redds.

The potential for the Riddle Creek population to maintain its historical spatial structure is highly compromised. The spatial structure was rated at moderate risk primarily due to low scores associated with habitat quality (Table A1-19). Habitat was rated as in poor condition at 57% of the 21 sites surveyed between 2007 and 2010. Many of these sites rated as in poor condition were located lower in the watershed where stream segments were sometimes found to be dry (Miller et al. 2010). Confidence in the habitat assessment was reduced given sites were not surveyed on Paul Creek and a portion of Riddle Creek due to a lack of access provided by private landowners. Habitat quantity was also reduced. The potential distribution of redband trout in the Riddle Creek watershed was estimated at 97% of the historical distribution (87 km), however based on the 2008 sampling effort only 65% (56 km) was actually occupied. Redband trout were not detected at sites located on Riddle Creek below the confluence of Smyth Creek (Miller et al. 2010). The configuration of habitat patches was rated as at moderate risk of not being viable. Although the river system is not highly dendritic, the presence of three substantial headwater tributaries provides some protection from stochastic catastrophic events and the possibility for multiple subpopulations. The Riddle Creek population is considered to have moderate potential for intra-population connectivity. Of the longest historical migratory corridor 98% is still accessible (Fig A1-8). There is no documentation of permanent barriers to migration besides the Round Barn Dam, which is located very low in the system. Passage at Smyth Dam has not been described. Habitat suitable for fostering a migratory life history is not present in the Riddle Creek watershed, however evidence of fish up to 300 mm suggests the possibility. An on the ground assessment of movement, and therefore connectivity, within the Riddle Creek population is necessary to adequately evaluate this metric.

Diversity scores suggested much of the diversity present 200 years ago may still be present today. The change in ecological diversity from historical to current condition was minimal, just 0.3% (Table A1-19). However, the lack of fish detected in the lowest reaches of Riddle Creek may represent a greater loss of ecological diversity than represented here. For the purpose of this population assessment the Riddle Creek population was considered to not express a migratory life history resulting in a lower score for the diversity metric. However, the presence of large individuals (>250 mm) may suggest multiple life history types may be expressed periodically. Further investigation into the movement and life history diversity of this population is necessary to adequately assess diversity and population viability.

**Table A1-19--Viability metrics, scores and rating for the Riddle Creek redband trout population.**

| Parameter | Value | Scoring | | | Viability Rating |
|---|---|---|---|---|---|
| **Abundance** | | | | | Moderate Risk |
| Estimate | 48,200 | | | 5 Very Low | |
| Lower 95% CI | 30,800 | | | | |
| Km of distribution | 84 | | | | |
| Fish/Km | 618 | | | | |
| n (sites) | 18 | | | | |
| **Productivity** | | | | | |
| %<100mm | 17 | 3 | | 3 Moderate | |
| %>200 mm | 10 | 0 | | | |
| n (fish) | 562 | | | | |
| n (sites) | 18 | | | | |
| **Spatial Structure** | | | | | |
| *Habitat Availability* | | | 2.7 | 2.7 Moderate | |
| Habitat Quantity: % historical occupied | 65 | 3 | | | |
| Habitat Quality (n=21) | | 1 | | | |
| % Good | 0.0 | | | | |
| % Fair | 43 | | | | |
| % Poor | 57 | | | | |
| Configuration | | 4 | | | |
| Stream order | 3 | | | | |
| No. of tributary junctions | 3 | | | | |
| *Connectivity* | | | 3 | | |
| % historical corridors accessible | 98 | 5 | | | |
| Rearing habitat available | No | 1 | | | |
| **Diversity** | | | | | |
| No. of life history types | 1 | 3 | | 4 Low | |
| Change in ecological diversity | 0.3% | 5 | | | |

Blitzen

The redband trout population in the Blitzen River basin was rated as at very low risk of not being viable. All four VSP parameters were scored as at low or very low risk. Abundance and productivity were scored high (Table A1-20). The 2008 population estimate exceeds the abundance viability benchmark by two orders of magnitude and average density measures were greater than 248 fish/km. Length frequency analysis of productivity show 36 percent of the population was less than 100mm reflecting high levels of reproduction and potential recruitment. Similarly, 10% of fish > 100mm are > 200mm indicating high intrinsic productivity and long term survival.

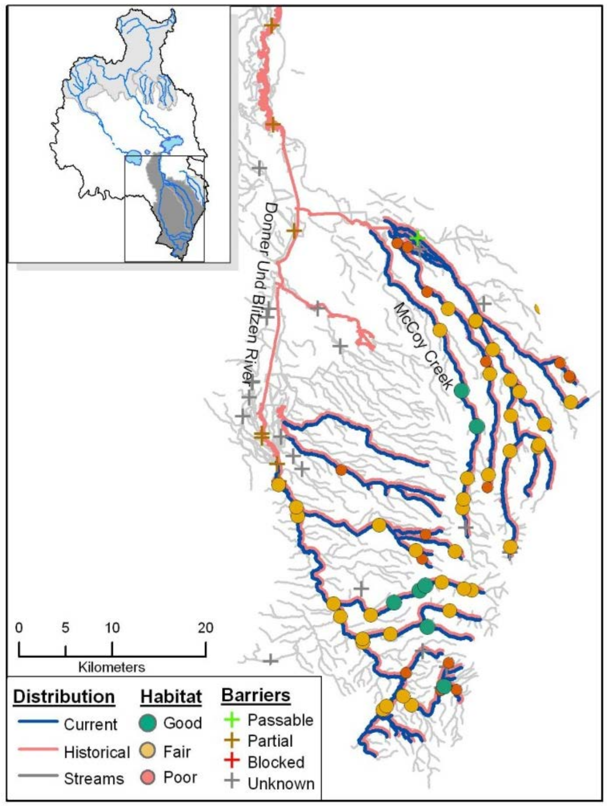


**Figure A1-4. Blitzen River redband trout population.**

The spatial structure of the Blitzen River population has been moderately impacted since pre-European settlement. While the dendritic configuration of the stream network minimizes the risk associated with catastrophic stochastic events and promotes the development of multiple subpopulations, the habitat quantity and quality measures suggest spatial structure may be altered. The population was estimated to occupy 66% (347 km) of the historical distribution (529 km) (Fig A1-9), and a majority (65%) of currently occupied habitat was rated as in 'fair' condition. Only 11% of the sites surveyed were rated as good quality. Within population connectivity was scored high and rated as at low risk. However, the metric does not elucidate the impact of irrigation activities within the basin. Seven irrigation dams occur on the Lower Blitzen River. None of the dams is a complete and permanent barrier, but in combination they can delay or prevent arrival at spawning grounds and potentially prohibit fish from moving upstream to seek cooler water (Bowers et al. 1999, Anderson 2009). An impassable irrigation diversion near the mouth of McCoy Creek prevents fish from returning to McCoy Creek to spawn. Oregon Water Resources Department (unpublished data) lists 43 surface water diversion points in the McCoy Creek basin. The location, status, and condition of these diversion points have not been verified, but many likely prevent movement during the irrigation season (Bowers et al. 1999).

There was uncertainty associated with the data used to evaluate the spatial structure metrics. First, this assessment likely underestimates historical distribution, particularly in the lower reaches of the Blitzen River where it flows through the Malheur Lakes National Wildlife Refuge. The historical distribution here is represented as a single, relatively simple, channel. Instead the historical stream channel was likely highly sinuous and composed of multiple braided channels resulting in a much greater stream distance than what was represented in this assessment. In addition, this assessment likely underestimates current distribution, which was based on the potential year-around occupancy of wade-able streams. Consideration of year-around occupancy in the large mainstem river, while unknown, could extend current distribution further downstream.

Scores comprising the diversity metric are quite high indicating a very low risk of not being viable (Table A1-20). The redband trout population in the Blitzen River expresses a minimum of two life history types, migratory and resident, indicating a relatively high degree of life history diversity. Further investigation may reveal a greater degree of diversity relative to run timing, age at maturity and other traits. Similarly, the analysis reflects little change in ecological diversity, just 1.5%. The lower elevations contain the greatest change in the proportion of distribution. This value suggests little change in genotypic and phenotypic diversity.

**Table A1-20--Viability metrics, scores and rating for the Blitzen River redband trout population.**

| Parameter | Value | Scoring | | | Viability Rating |
|---|---|---|---|---|---|
| Abundance | | | | | Low Risk |
| Estimate | 242,600 | | | 5 Very Low | |
| Lower 95% CI | 195,900 | | | | |
| Km of distribution | 407 | | | | |
| Fish/Km | 615 | | | | |
| n (sites) | 47 | | | | |
| Productivity | | | | | |
| %<100mm | 36 | 5 | | 5 Very Low | |
| %>200 mm | 10 | 0 | | | |
| n (fish) | 2584 | | | | |
| n (sites) | 69 | | | | |
| Spatial Structure | | | | | |
| *Habitat Availability* | | | 3.7 | 3.7 Low | |
| Habitat Quantity: % historical occupied | 65.6 | 3 | | | |
| Habitat Quality (n=63): % Good | 11 | 3 | | | |
| % Fair | 65 | | | | |
| % Poor | 24 | | | | |
| Configuration: Stream order | 5 | 5 | | | |
| No. of tributary junctions | >5 | | | | |
| *Connectivity* | | | 5 | | |
| % historical corridors accessible | 100 | 5 | | | |
| Rearing habitat available | Yes | 5 | | | |
| Diversity | | | | | |
| No. of life history types | 2 | 5 | | 5 Very Low | |
| Change in ecological diversity | 1.5% | 5 | | | |

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# APPENDIX 2

# DESCRIPTION OF VIABILITY METRICS

**Preface**

Contained within this document are metrics proposed to assess viability of Great Basin redband trout populations. The Oregon Department of Fish and Wildlife has initiated a conservation planning process for Great Basin redband trout. The resultant conservation plan revolves around an assessment of viability for each population. Populations that are identified at high risk of not being viable are further evaluated using a limiting factor analysis and conservation actions are then recommended to specifically address shortcomings in factors affecting their long term sustainability. Thus, the entire planning process is shaped by the initial evaluation of viability.

ODFW's Native Fish Conservation Policy (ODFW 2002) recommends a suite of biological variables (e.g. abundance, survival, and persistence) by which to assess all native fish populations. In the case of Great Basin redband trout, the data required to effectively assess many of the variables are nonexistent or the variables do not necessarily pertain to a non-anadromous species. Instead population viability is assessed using recommendations and guidelines outlined in McElhany et al. (2000). A guiding document for the conservation of salmonid populations, this technical report describes four attributes by which to effectively assess population viability including abundance, productivity, spatial structure, and diversity. Although recommendations were made specifically addressing anadromous forms, the concepts are directly applicable to interior species.

The design of metrics to evaluate each of the four attributes was largely influenced by the datasets currently available. For Great Basin redband trout, data and specific knowledge are extremely limited. Only metrics assessing abundance and productivity incorporate actual population scale sampling data, and even in those cases, the effectiveness of the metric is compromised by the lack of long term and truly appropriate datasets. The spatially mediated processes described by spatial structure and diversity are considered vital for the viability of redband trout populations and may be more important than abundance and productivity. Thus, it is necessary to include an assessment of these metrics here; however, empirical data pertaining to these parameters are essentially non-existent. As a result this conservation plan uses indirect and surrogate measures in an attempt to represent spatial structure and diversity.

It is important to note that in all metrics the paucity of data necessary to effectively evaluate each criteria and our limited understanding of population level processes makes evaluating population viability challenging. Metrics proposed here are all rooted in fundamental biological principles relevant to Great Basin redband trout. However, the indirect methods employed to measure each parameter and the proxy measures both rely on critical assumptions. These assumptions create a high level of uncertainty as to the adequacy and accuracy of the metrics. Thus, the current design and implementation of the metrics is intended to serve as the initial step in an iterative process to effectively assess population level sustainability. Through the development and application of these metrics the Planning Team has identified many shortcomings that serve as the basis for adjusting and fine tuning the assessment as recommended in the RME section of the conservation plan.

**Table A2-1--Overview of redband trout viability metrics and scoring.**

| Parameter | Goal | Objective | Metric | Scoring | | | |
|---|---|---|---|---|---|---|---|
| Abundance | To maintain population size large enough to avoid deleterious effects of small population size. | Maintain populations > 2,500 age 1+ fish | Abundance and density of age 1+ fish. | **A/P Score:** Mean of the abundance and productivity scores | | | Overall Viability: see Viability Matrix on page 27. |
| Productivity | To maintain productivity rates sufficient to support a net replacement or higher. | Maintain a minimum proportion of juveniles and large adults, indicative of long term survival and reproductive success. | Proportion of population in smallest (<100mm) and largest size classes (>200+mm). | | | | |
| Spatial Structure | To manage the physical habitat template to conserve and restore natural spatially mediated | Maintain natural distribution through habitat availability | **Habitat Quantity** – % of historical distribution currently occupied<br>**Habitat Quality** – Percentage of habitat rated as good, fair, or poor by HabRate model<br>**Habitat Arrangement** - | **Habitat Score:** Mean of the three habitat availability metrics | **Spatial Structure Score:** Choose habitat or connectivity score | **SS/D Score:** Mean of the two spatial structure and | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | processes in order to maintain population level diversity and viability. | | spatial arrangement of habitat patches | | indicative of greatest risk. | diversity scores | |
| | | Maintain historical levels of connectivity | **Accessible migratory corridors** longest current continuous stream vs. historical | **Connectivity Score:** Mean of two connectivity metrics | | | |
| | | | **Potential for migratory behavior** - Migratory adult rearing habitat available | | | | |
| Diversity | Preserve phenotypic diversity as determined by spatially mediated processes | Maintain phenotypic expression by maintaining known attributes of life history types | **Life History Diversity –** Number of life history types | **Diversity Score:** Mean of life history and ecological diversity metrics | | | |
| | | Maintain phenotypic expression by maintaining occupancy in a natural variety of available habitat types. | **Ecological Diversity –** Average cumulative % change in occupancy across elevation bands | | | | |

**Abundance**

Introduction

The size of a population plays a significant role in its viability and is an important determinant of risk both by itself and in relation to other population level factors, such as productivity and diversity (McElhany et al. 2000). The risk of not being viable varies inversely with abundance where small populations face higher extinction risks relative to large populations. Small populations lose adaptive variation and gain maladaptive variation at a greater rate resulting in lower fitness and a higher probability of extinction (Mills and Smouse 1994, Lande 1995 as cited in McElhany et al. 2000). All else being equal, large populations are more resilient and more likely to persist in the face of environmental change, whereas small populations can be negatively affected by a suite of processes that effect population dynamics. These processes affect small populations differently than large populations and include deterministic density effects, genetic processes, environmental variation, demographic stochasticity and ecological feedback. Some of these processes are more important than others; however they are all interconnected and often have a synergistic influence on population dynamics. A brief review of these processes highlights the higher risk associated with small populations.

**Deterministic density effects**

Density dependent effects include two opposing mechanisms: compensation and depensation. Compensation describes the increase of productivity that occurs with a decline in density. When population abundance decreases more resources are available to individuals resulting in higher productivity. This inverse relationship acts as a stabilizing influence on population size and offers substantial resiliency because any decline in abundance is offset with an increase in productivity. Depensation has the opposite effect, one that is significant as population size decreases below a certain low level. The inability to find mates (Dennis 1989), a randomly skewed sex ratio (Gabriel and Büger 1992), and increased predation rates (Peterman 1987) have all been documented as mechanisms of depensation, operating singly and in concert (Stephens and Sutherland 1999). Depensation processes increase the extinction risk of small populations because any decline in abundance further reduces the number of offspring that can be produced, resulting in a rapid decline toward extinction. In the event that extinction is avoided, depensation processes operating at low levels of abundance slows recovery, leaving a population vulnerable to environmental variation, maladaptive genetic processes, and catastrophe.

**Environmental Variation**

Natural variation in the physical or biological environment can dramatically reduce survival of individuals within a population. Based on sheer numbers, large populations are more resilient to changes in their physical environment. High abundance ensures enough individuals survive and successfully reproduce, effectively maintaining population size. However, small populations are especially vulnerable to environmental variation because any declines in an already small population have the potential of completely eliminating the entire population. If the population is not eliminated it is then even more susceptible to the effects of demographic and genetic processes as well as further declines due to environmental variation and catastrophe.

Highly variable environmental conditions are common for redband trout populations in the high desert. Stream flow and water temperature varies with water year to such a degree that in dry years (below normal precipitation) streams that typically flow year around may be dry. Such changes in conditions and chance events, such has high scouring flows, can reduce survival, fecundity, and productivity to low levels for extended periods of time. Small populations are less able to absorb the declines in survival associated with varying environmental conditions than large populations.

**Genetic Processes**

Small populations are extremely vulnerable to the loss of genetic diversity. The processes that are typically responsible for this loss include genetic drift and inbreeding depression. Genetic drift is the change in frequency of an allele in a population due to random chance, as opposed to a selective, adaptive force. The distribution of genes is based on the individuals of the previous generation that survived and successfully reproduced, but their survival and subsequent reproduction was not a result of genetic adaptations. Genetic drift in small populations often results in the loss of alleles and hence genetic diversity. This loss of diversity could limit a population's ability to respond adaptively to future environmental changes. The smaller a population the sooner genetic drift will have a drastic effect. Inbreeding occurs when closely related individuals mate, which has greater probability of occurring in smaller populations as there are fewer opportunities available for mating with an unrelated individual. The negative effects of inbreeding occur when two individuals, both carrying a recessive deleterious trait, mate. The result is an increased frequency with which deleterious recessive alleles are expressed, which could reduce the viability and reproductive capacity of individuals. The chance of two individuals being recessive for the same gene increases with smaller population size. The decrease in survival and reproduction due to inbreeding is called inbreeding depression.

**Demographic Stochasticity**

The variability in population growth rates arising from random differences among individuals in survival and reproduction is referred to as demographic stochasticity. Natural individual variation in factors associated with fecundity, fertility, and successful reproduction in general results in some individuals producing fewer progeny than average and some producing more. Similarly the sex ratio of offspring varies among individuals where some may produce a greater number of one gender than the other. This variation among individuals can have an especially significant effect at small population sizes (Primack 1998). For instance, a random decrease in birth rates in any given year may result in lower abundance which will further expose an already small population to the effects of environmental variation, depensation, and genetic processes.

**Ecological Feedback**

Ecological feedback refers to the positive influence of abundant salmonid populations on healthy ecosystem function that ultimately benefits future generations. Examples of positive ecological feedback for anadromous salmon are abundant. Two examples worth noting include the maintenance of spawning bed gravels and transport of marine derived nutrients into terrestrial ecosystems. The scouring of gravel during redd construction beneficially alters the size distribution of gravel and stability of streambed materials for the next year's spawners (Montgomery et al. 1996). Similarly, the decay of spawned out carcasses provides the necessary micro-nutrients utilized by numerous other aquatic and terrestrial plants and animals which further enhance the quality of the habitat and support the growth of future generations (Bigler et al., 1996 Cederholm et al. 1999). Although such ecological feedback is measurable at high abundance, it follows suit that at low levels of abundance populations have less of an ecological influence and thus provide less benefit to future generations.

Clear examples of ecological feedback have not been examined for interior redband trout specifically. However it is logical to assume that the same processes also apply to redband trout. The mechanics of redd construction likely helps maintain spawning habitat by clearing out fine sediment. Similarly, although redband trout are not sources of marine derived nutrients, migratory individuals likely carry nutrients from highly productive habitats lower in the watershed to nutrient limited headwater streams.

**Rationale for developing an abundance criterion**

Due to the important role abundance plays in the determination of risk, any viability assessment should include an evaluation of population size. Therefore this conservation plan has developed a viability criterion for population abundance based on our understanding of the processes mentioned above and the guidelines provided by the National Marine Fisheries Service (McElhany et al. 2000). Although these guidelines were developed specifically for anadromous species many are relevant to interior populations of redband trout. The guidelines most pertinent to redband trout populations include:

1. A population should be sufficiently large to maintain its genetic diversity over the long term.

2. A population should be large enough to have a high probability of surviving environmental variation.

3. A population should have sufficient abundance for compensatory processes to provide resilience to environmental and anthropogenic perturbation.

The challenge is determining an abundance threshold above which a redband trout population is viable according to the guidelines listed above. At what point is a small population too small? At what size do depensation and demographic stochasticity have detrimental effects on population viability? The Planning Team knows that some redband trout populations exist at very low abundances (i.e. Prater Creek); however it is not known if their genetic integrity or population dynamics have been compromised to a point where extinction is not a question of 'if', but rather 'when'.

The difficulty in identifying such a threshold is related to the fact that our understanding of the population dynamics and the genetic integrity of redband trout in this SMU, or of redband trout in general, is very poor. Little is known about redband trout in high elevation desert environments. It is the least studied species of the western salmonids (Schill et al. 2007). Basic datasets describing long term trends in abundance, age and size at maturity, recruitment and survival simply do not exist (except Schill 2009 and Kunkel 1976). Recovery plans for other species have used various population viability analyses to assess the long term viability of particular populations (WLCTRT 2006, ICTRT 2007). However, due to the lack of appropriate datasets this tool is unavailable for redband trout. Thus, development of a criterion in which biologists are confident that populations above a certain size are unlikely to suffer the perils common to small populations must necessarily be based on information of other species, the best educated guess, and simple 'rules of thumb'.

When considering a population size threshold adequate for preserving the genetic diversity of a population, the concept of effective population size ($N_e$) serves as a useful tool. The concept of effective population size plays an important role in conservation management of fishes and is a topic that has received much attention in the conservation literature (Franklin 1980, Waples 1990, 2004, Lande 1994). The effective population size describes the rate of genetic drift and is directly related to the rate of loss of genetic diversity and rate of increase in inbreeding within a population (Wright 1969, Reiman and Allendorf 2001). Simply put, effective population size is the number of individuals in a population who contribute offspring to the next generation. Not all individuals have the same probability of reproducing and making a contribution to the next generation. This differential reproductive success can be attributed to unequal sex ratios, nonrandom mating, fecundity and sterility. Effective population sizes are usually lower than the ecologically observed population sizes and are generally 10-20% of the total number of adults (Allendorf and Ryman 2002).

This conservation plan uses the '50/500' concept as a general starting point for recommending an effective population size that is consistent with long term viability (Franklin 1980, Soule 1980, Nelson and Soule 1987). This concept asserts that at least 50 individuals per generation are necessary to avoid the immediate short term effects of inbreeding depression. However, if a population is to maintain adaptive genetic variation over the long term, a population must maintain 500 or more individuals per generation to avoid the deleterious effects of genetic drift (see Allendorf and Ryman 2002 for review). Many conservation plans have used this guideline to establish a minimum abundance benchmark for species at risk, including salmonids (Allendorf et al 1997; Hilderbrand and Kershner 2000).

It is important to note that the guidance provided by this concept is very general and should be accepted only with limitation. These recommendations were based on very general applications of basic genetic principles, and were estimated from data obtained from only one species (*Drosophila melanogaster*) and, consequently, are somewhat oversimplified (Shaffer 1981, McElhany et al 2000). A more detailed approach involves gathering information on the degree of genetic variability and the breeding structure of the species of interest. Given this information, it should then be possible to determine what size population would provide a representative sample of the genetic diversity and what size would be necessary to assure that none of this variability would be lost due to inbreeding and genetic drift (Shaffer 1981). Thus, the '50/500' rule should be viewed as a very rough guideline rather than simple prescription.

The application of the '50/500' rule requires an estimate of the actual $N_e$ of each redband trout population. Direct estimates of $N_e$ are possible to generate but are generally hard to obtain. They require either hard to obtain parameters on population demographics and breeding structure, such as lifetime family size, or extensive information on genetic population structure (McElhany et al. 2000, Rieman and Allendorf 2001, Schill 2009). Such rigorous data requirements make it very difficult to make direct estimates of effective population size for the majority of salmonid populations, particularly Great Basin redband trout populations. In the absence of direct and measured estimates of the effective population, this parameter is often inferred from the total population size or the total number of spawning adults. This inference requires knowledge of the relationship of the effective population size to that of the actual population size or the total number of adults ($N_e/N$) (Frankham 1995, Waples 2004, Schill 2009). Generally, $N_e/N$ ratios for salmonids have been found to range between 0.2 and 0.3. Allendorf et al. (1997) suggest that a ratio of 0.2 is appropriate for wild, coastal salmon, whereas McElhany et al. (2000) recommended a ratio of 0.3 based on studies of Chinook salmon. Reiman and Allendorf (2001) estimated $N_e/N$ for bull trout to range between 0.15-0.27 and observed that $N_e$ was 0.5-1.0 times the number of spawners detected each year.

In a one of a kind study of Idaho's high desert redband trout, Schill (2009) used field derived data in concert with simulation modeling to estimate $N_e/N_{adult}$ ratios and found they ranged between 0.4 - 0.7. Since Oregon's Great Basin redband trout populations are more similar to those of Idaho redband trout than other salmonid species, this conservation plan will use a $N_e/N_{adult}$ ratio of 0.4 to develop guidelines for abundance. Choosing to use the lower end of the range results in a larger recommended $N_e$ and assures that the guideline errors on the side of caution given the high degree of uncertainty. This is particularly important considering most Great Basin redband trout populations are isolated. These populations do not receive any gene flow from other populations that may act as a source of genetic variation. Given a $N_e/N_{adult}$ ratio of 0.4, a population must contain 1,250 adults to meet the minimum effective population size guideline of 500 individuals. However, size and age at maturity for redband trout is highly variable across the landscape and varies with sex and stream order (Schill 2009) making accurate counts of adults difficult to estimate. Plus the discrimination of recently matured and immature individuals during routine inventory and monitoring efforts is challenging, further obscuring the total number of adults present. Based on findings of Schill (2009), this conservation plan assumes an average of 47% of fish >100mm in a population are adults. In order for a population to contain 1,250 adults it should contain at least 2,500 individuals > 100mm to avoid the genetic effects of inbreeding and genetic drift. This value is similar to that recommended for inland cutthroat trout (Hildebrand and Kershner 2000), and Pacific Salmon species (Allendorf et al. 1997).

McElhany et al. (2000) provided a guideline that a population should be large enough to have a high probability of surviving environmental variation. The influence of environmental variation on a population's size is a relationship that requires an exceptionally long time series to fully understand and adequately describe. In addition, the relationship is often confounded by other factors that also affect population abundance including demographic stochasticity and deterministic disturbances such as anthropogenic habitat degradation. As a result, determining the effects of environmental variation can be particularly difficult. In the case of Oregon's Great Basin redband trout, long term datasets of population abundance and knowledge of trends in the biological and physical environment simply do not exist. Thus to develop a minimum threshold above which one can be certain that populations can sustain themselves in highly variable environments is not possible. It is tempting, and logical, to assume that since populations have survived for centuries and weathered cycles of extreme variation in the past, maintaining current levels of abundance is minimally sufficient for long term viability in the face of environmental variation. However, there is no guarantee that conditions experienced in the future will not be worse than those experienced in the past. The effects of global climate change are likely to result in very different environmental patterns than populations have previously survived.

McElhany et al. (2000) report that depending on the degree of natural variation in abundance a minimum of 1000 to 10,000 individuals is necessary for a population to be sustainable given the effects of long term environmental variation (Belovsky 1987, Goodman 1987, Thomas 1990). This estimate ranges an order of magnitude and, although it is applicable to all species, it reflects the uncertainty and complexity characteristic of the relationship. In the case of high desert redband trout populations, the minimum abundance is likely on the lower end of this range. Relative to other species, such as insects and the most variable bird and mammal species, redband trout populations are fairly stable, especially given they are iteroparous and have overlapping generations (Thomas 1990, McElhany et al. 2000). In addition, redband trout are very plastic and highly adaptive (Li et al. 2007). Populations, even at seemingly low abundances, are able to quickly adapt to changing environmental conditions. Given the uniquely adaptable nature of redband trout populations, the number of individuals necessary for a population to survive fluctuations in environmental conditions maybe be less than for other species. In the absence of a data derived abundance threshold relative to environmental variation, this conservation plan assumes the threshold established to protect against inbreeding and genetic drift (2,500 individuals) is minimally adequate to protect against the effects of environmental variation.

While this conservation plan establishes a minimum abundance threshold for viability, it ranks risk according to the average density of fish in a population (Table A2-1). The criterion is constructed in this manner for two reasons. First, the effects of depensation are largely a function of low density rather than absolute abundance. The third guideline suggested by McElhany et al. (2000) recommends that a population should be large enough to avoid the effects of depensation, such that compensatory processes need to be sufficient enough to provide resilience to environmental and anthropogenic perturbation. However, as with other population size guidelines, the data necessary to determine the point in which compensation no longer exists and depensation becomes significant do not exist. In light of this information gap and relative importance of the role of density, the ranking of risk according to mean density attempts to capture the effects of density dependent processes within a population. The risk categories are based on those used for range-wide assessments of interior cutthroat trout species (Shepard et al. 2005, May and Albeke 2005) and Trout Unlimited' s Conservation Success Index (Williams et al. 2007) rules for Goose Lake and McCloud River redband trout. Given the uncertainty associated with the point at which depensation becomes significant; the intent is to implement a broad brush evaluation rather than a precise estimate. Second, population level abundance estimates are not available for all redband trout populations. The most recent dataset available to assess viability (Miller et al. 2010) combines many of the small populations into one population level stratum. For example, in the Malheur Lakes SMU, Rattlesnake, Poison, Cow, Prater, and Coffeepot populations are grouped into the East Burns stratum. Similar grouping were made in the Catlow Valley and Goose Lake SMUs. This was necessarily done for logistical purposes, but does not provide an estimate of abundance (with confidence limits) for each population. As a result, the larger populations have quantitative estimates of abundance while many of the small populations, which arguably require closer monitoring, may only have a few site level density estimates. Thus establishing a criterion based on mean population density provides a higher likelihood of assessing viability for populations without robust population estimates (albeit sacrificing confidence). Obtaining population level abundance estimates for redband trout has proven to require an extensive and expensive field effort given high between-site variability and the remote nature of the populations (Miller et al. 2010, Schill 2009). Although precise population estimates are desirable, the likelihood of regularly and frequently assessing population level abundance with acceptable levels of confidence in the future is slim. Until methods and resources can be secured to accurately estimate population abundance in all redband trout populations, this conservation plan will rank the risk of not being viable on the mean density, acknowledging the high degree of uncertainty, particularly in small populations. One risk of evaluating risk based on density is sampling data may show a populations exists at high density, but total abundance may actually be less than 2,500 fish. If this occurs it will likely happen in populations with a limited distribution. At high density (0.24 fish/m) a population would require nine kilometers to achieve an abundance of 2,500. Thus for populations rated as high density but distributed in less than 9 km the risk rating is upgraded one category.

In addition to the three guidelines outlined in this conservation plan, McElhany et al. (2000) also proposed a guideline in which a population should be sufficiently abundant to provide important ecological function. Although ecological feedback is clearly an important element in the ecology of salmonids, there is currently very little guidance available to indicate at what levels of abundance the effects of ecological feedback may be significant for ocean going salmon, much less interior redband trout. Because of the uncertainty associated with the role of ecological feedback for redband trout populations, this concept did not play a significant role in the development of the abundance criterion.

In summary, the data and analyses necessary to establish a minimum threshold of abundance in light of genetic and density dependent processes, and environmental variation do not exist for Great Basin redband trout populations. Given this data gap, this conservation plan has established a minimum abundance threshold of 2,500 individuals and a framework to rank risk according to density. This threshold is based on widely accepted findings in the conservation literature, modeling exercises, empirical research on redband trout and other species, and best professional judgment. This criterion will be applied until research specific to Great Basin redband trout results in a more accurate and robust evaluation.

**Abundance metric**

**Goal -** To maintain population size large enough to avoid deleterious effects of inbreeding, survive environmental variation, be resilient to disturbance and maintain spatial structure.

**Objective –** Maintain a population size > 2,500 age 1+ fish and a density of 50 fish/mile

**Table A2-2 Metric –** Abundance and density of age 1+ fish

| Fish / mile | Risk | Score |
|---|---|---|
| > 400 (248 / km), total pop >2,500 | Very Low | 5 |
| 50 - 400, total pop >2,500 | Low | 4 |
| < 50 (31/km), total pop >2,500 | Moderate | 3 |
| < 50 (31/km), total pop <2,500 | High | 1 |

**Productivity**

**Introduction**

Productivity, as measured by trends in abundance, describes a population's growth rate over its life cycle. A sustainable population is able to maintain a stable or positive growth rate by producing enough offspring to minimally replace the adults in the parent generation. A population expressing a negative growth rate that is consistently unable to replace itself is at a high risk of extinction. Similarly, a population's intrinsic productivity is a measure of population growth in the absence of density dependent factors, i.e. at low abundance. Populations with high intrinsic productivity are resilient and able to rapidly rebound from periods of low abundance caused by environmental variation. Populations with low intrinsic productivity take longer to recover and therefore remain at low levels of abundance further exposing them to the deleterious processes associated with small population size, such as depensation, genetic drift, and demographic stochasticity. Theoretically, a population will exhibit its greatest growth immediately following a period of severely constraining environmental or anthropogenic conditions. As favorable conditions are restored population growth and therefore abundance will rebound. During periods of extended favorable conditions productivity may plateau or even decrease as the population reaches carrying capacity and density dependent factors become increasingly significant. A population's ability to rebound from short-term perturbations is a function of its resilience.

Measures of productivity describe a population's performance in response to the habitat and environment it occupies throughout the life cycle. Habitat quality and quantity are important drivers of intrinsic productivity. Extensive high quality habitat buffers extreme environmental conditions such as drought. The higher quality habitats can serve as refuge during severe conditions. Following short-term perturbations a population residing in high quality habitat is poised to quickly respond, reproduce, and re-colonize lower quality habitats once favorable conditions return. Populations without such high quality refuge will respond at a slower rate and to a lesser degree. In addition to habitat condition, the specific biological attributes of a population can also influence productivity. All things being equal, a population that expresses a migratory life history is more resilient than a resident population. Large migratory adults are more fecund, can dig deeper, more scour resistant redds, and are more likely to colonize new habitats than their resident counterparts.

**Rationale for developing a productivity criterion**

Ideally this plan would assess productivity using a measure of population growth rate over the entire life cycle and, in the best of all circumstances, also include measures of stage specific productivity (McElhany et al. 2000). Typically productivity is evaluated using trends in abundance and fitting these data to stock –recruitment curves. This method gauges whether or not a population is replacing itself between generations. Other, ancillary data such as size at maturity or the number of life history strategies expressed also contribute important information to long term population viability (McElhany et al. 2000). These data may provide opportunity to detect changes that may not influence current population dynamics, yet may change a population's overall productivity over time.

Considering productivity and population growth rate as they relate to abundance and viability, McElhany et al. (2000) provide six guidelines for assessing the productivity of salmonid populations. Three of these guidelines are particularly relevant to non-anadromous species that are free from significant hatchery influence such as redband trout. These guidelines include:

1. Population's natural productivity should be sufficient to maintain a viable level of abundance.

2. A viable population should not exhibit trends or shifts in traits that portend declines in population's growth rate.

3. A population should not exhibit sustained declines in abundance that span multiple generations.

In regard to Great Basin redband trout populations, data are not available to directly assess productivity and population growth rates. Trends in abundance do not exist at the population scale, and at the SMU scale reliable abundance estimates only exist for years 1999 and 2007-10 (Dambacher et al. 2009, Miller et al. 2010). Even though it may be possible to get a general sense of change in abundance at the SMU level, these data are not adequate to evaluate long-term trends and fluctuations in population abundance and productivity.

Other metrics, such as age at maturity and size at age, which may be particularly useful especially in regard to the guidelines provided by McElhany et al. (2000), are also not available in part because there is a lack of basic data specific to age and growth of redband trout in general and in high desert environments specifically (Schill 2009). Two studies have estimated the age of redband trout in the Oregon portion of the Great Basin (Kunkle 1976, Anderson 2009). These studies are difficult to apply to an assessment of status for two reasons. First, both studies primarily evaluate the age of large migratory fish. Although important, their findings may only apply to the few populations that express a migratory life history. Second, both studies estimated age of individual fish using scale analysis, but neither study validated their aging techniques with direct measures of age and growth. A recent ageing validation study conducted in the high desert of Idaho found the use of scales to estimate age of redband trout to be unreliable (Schill 2009).

The paucity of the data necessary to evaluate productivity and our limited understanding of how productivity expresses itself in populations inhabiting desert streams makes evaluating population growth a challenge and forces this plan to find alternative methods to gauge productivity at some level. This conservation plan has chosen to develop surrogate measures of productivity in hopes of establishing a starting point for assessing population viability. The development of surrogate measures necessarily requires assumptions to be made. These assumptions create a high level of uncertainty as to the adequacy and accuracy of the metrics in describing productivity. As a result, assessing productivity is identified in the RME chapter as being a critical uncertainty that warrants further research and investigation.

The Native Fish Status Report (ODFW 2005) used a variety of surrogate factors (life history types, connectivity, presence of non-native species and habitat quality among others) to qualitatively assess whether or not a population was minimally able to rebound rapidly after periods of low abundance. This evaluation relied heavily on professional judgment. Even though the approach was less rigorous than desired it did provide a useful inventory of factors that influence intrinsic productivity in each population. This conservation plan hopes to take the analysis one step further and incorporate population specific data to evaluate yearly reproductive success.

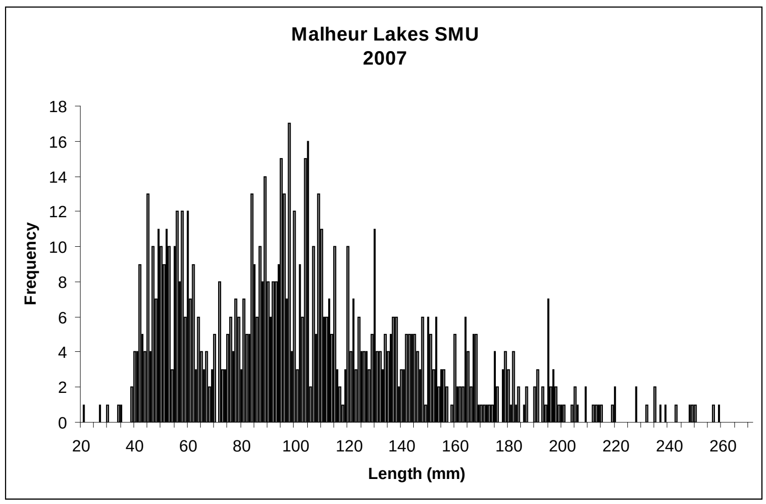


**Figure A2-1.** Length Frequency histogram for redband trout collected from representative sample sites in the Malheur Lakes SMU in 2007 (Native Fish Investigations Project).

In the absence of proper measures of productivity, length-frequency histograms are employed as a general indicator of potential population growth. The typical length-frequency histogram for Great Basin redband trout populations shows a prevalence of fish in the lower size classes, less than 150 mm (ODFW unpublished data) (Figure 1). The smaller size classes represent potential recruitment into the spawning population in the next 1 -3 years (Schill 2009, Kunkel 1976). If the percentage of fish in the small size classes is relatively high, then it is assumed that productivity is high and environmental conditions are favorable (sensu Zoellick et al. 2005). If the percentage of the population in the lower size classes is low and suggests a possible year class failure, then it is assumed productivity is low, environmental or habitat conditions are poor and the population may be unable to replace itself. Along the same lines, the percentage of fish in the largest size class serves as a longer term indicator of the quality of environmental conditions and potential productivity. A decrease in the proportion of large fish may indicate significant deterioration of habitat conditions that affect the population over the course of the life cycle. Loss of the large, highly fecund, migratory individuals results in lower productivity and may indicate the loss of a life history type. The drawback of this approach is the analysis of proportions may mask an actual increase or decrease in abundance of a particular age class. For example, if the total number of fish in the 100mm – 200mm size class declines, then an increase would be reflected in the proportion of fish <100mm.

This approach adheres to the intent of the guidelines suggested by McElhany et al. (2000) in that it establishes a mechanism by which to evaluate indicators of productivity. While length frequency analysis does not provide an absolute measure of population replacement, it does identify instances when recruitment may be diminished. Populations in which the proportion of fish <100mm is continually low, may be suffering from sustained declines in recruitment that could translate into declines in abundance. Similarly the absence of large adults suggests a loss of significant life history traits and provides other cues of potentially decreased productivity. Length frequency analysis cannot provide a definitive measure of productivity, but instead can serve as a general indicator of recruitment and can identify populations of concern that warrant further evaluation.

One of the challenges to utilizing length-frequency histograms as an indicator of realized productivity is determining the cutoff between ‘high’ and ‘low’ proportions for an age or size class. Datasets that lend themselves to the examination of the relationship between size class distribution and population growth rate do not exist. In the absence of these data and associated analyses, benchmarks were created simply based on population data collected in 1999 (Dambacher et al, 2009), 2007-10 (Miller et al. 2010), and (Zoellick et al. 2005). The 1999 and 2007-10 datasets included representative samples for all populations and were collected during above and below normal water years.

Using the 1999 and 2007-10 datasets the proportion of the population in each of three size classes, <100mm, 100-200mm, and >200mm, each year for all populations were calculated. Although length at maturity for these populations is unknown, it is assumed that the <100 mm size class is comprised solely of juvenile fish based on studies of populations in Idaho that reside in similar environmental conditions (Schill 2009). The largest size class, >200 mm, is predominately mature fish and the 100-200mm size class represents a mix of immature and mature individuals (Schill et al 2010). Schill (2009) found redband trout in 3rd and 4th order streams matured later and at larger sizes than trout in 1st and 2nd order streams. He also found that males matured at smaller sizes and earlier than females. Given this variability in the size at which redband trout mature our focus is on size structure, specifically the percentage of all fish <100 mm (juveniles) and the percent of all fish over 100mm that were >200mm (adults). The Planning Team found that the percent of fish <100 mm ranged between 20-32% and the percent of fish >100 mm that were 200+mm ranged between 7-21%.

A study in the southwest desert basins of Idaho compared the size structure of redband trout populations in four drainages between the 1970s and 1990s (Zoellick et al. 2005). Even though the data are not directly comparable to ODFWs because the data are pooled over a period 8 or 10 years, their results do provide additional information regarding the degree of potential variation. The proportion of fish in the <100mm size class ranged between 16 and 60%. The proportion of adults in the >200mm size class varied between 0 and 6%. The authors explained that values of 25% or lower for the <100mm size class were indicative of low productivity and poor environmental conditions, whereas values of 44% or higher were indicative of higher productivity and more favorable conditions. It is worthy to note that for one basin in particular 16 % of the population was in the <100mm size class in the 1970s. Twenty years later the proportion had increased to 46%, indicating that populations with such a low proportion of fish in the lowest size class were still resilient over that time period given favorable conditions.

Based on the datasets described above, benchmarks were developed by which to generally evaluate productivity of Great Basin redband trout populations. Ideally populations will be evaluated using fish length data collected over multiple years (2-5 years) (sensu Zoellick 2005) to minimize the effect of season of sampling (spring vs fall) and extreme population fluctuations (Platts and Nelson 1988). Populations are scored according to the proportion of the fish sampled <100mm and the proportion of fish >100mm that are over 200mm. A population is first scored according to the percentage of juveniles.

A point is added to or subtracted from that score if the proportion of fish >100mm that are >200mm is greater than 15% or less than 7% respectively.
There is concern that this metric may misrepresent populations occupying relatively small stream channels where the ultimate size of a fish is limited by the size of the habitat. In these cases the habitats, and therefore the populations, may not have the potential to contain (many) fish greater than 200+mm but may still be highly productive and persistent (Schill et al 2010). While the risk of misrepresenting these populations is real and possible, the potential error is on the side of greater risk, and if nothing else, will result in increased monitoring and conservation efforts and ultimately do no harm. However, chances are, populations in these sorts of habitats are likely at higher risk of not being viable due to spatial structure and diversity related issues and in the end may warrant further conservation actions.

It is important to note that since this metric is primarily based on data that describe current conditions across the landscape, one must inherently assume that all populations are collectively resilient and viable. These values represent our best guess given the data available and are not in any way to be taken as absolute. The intention is to provide a general indicator of productivity and not necessarily a precise measure. Also, this metric indirectly reflects productivity in regard to a relative level of recruitment into the population and long term survival. A measure of biomass would directly relate to habitat condition, an evaluation particularly pertinent to this conservation plan.

**Productivity metric**

**Goal -** To maintain productivity rates sufficient to support a net replacement or higher or great enough to allow the population to rapidly return to abundance targets after perturbations.

**Objective –** Maintain a minimum proportion of juveniles and large adults, indicative of long term survival and reproductive success.

**Table A2-3 Metric –** Proportion of population in smallest and largest size classes

| % of fish <100mm | Juvenile Score | % of fish >100mm that are 200+mm | Adult Score | Final Score | Risk |
|---|---|---|---|---|---|
| >25% | 5 | > 15% | +1 | 5 | Low |
| 25 - 15% | 3 | 15 – 7% | 0 | 3 | Moderate |
| <15% | 1 | < 7% | -1 | 1 | High |

## Spatial Structure

### Introduction

The spatial structure of a population describes the geographic distribution and the processes that affect that distribution (McElhany et al. 2000). The distribution of a population is largely a function of the size, arrangement and stability of patches of suitable habitat. The occupancy of these patches is determined by intra-population dynamics, distance between patches, and dispersal rates. There must be sufficient high quality habitat to support a population and habitat areas must be connected so that fish can move from one area to the next as their life history dictates. Typically, spatial structure is described in terms of metapopulation theory using theoretical models to describe the temporal and spatial relationship among patches. The population structure of salmonids may range from a panmictic population, where all individuals are potential partners of those of the opposite sex, to a complex structure where a series of 'subpopulations' exist in dynamic relationship. For example, source-sink models describe a structure where habitat areas differ in quality. The habitat differential results in a dynamic where some subpopulations have higher productivity (sources) and others have lower productivity (sinks). The sinks are not self-sustaining and only persist due to influx from other subpopulations. (see McElhany et al. 2000 for review of spatial structure models). A population exhibiting a complex metapopulation structure such as this may have quite different dynamics, and therefore degree of persistence, than a panmictic population of the same aggregate size (Hanski & Gilpin 1991).

Ignoring factors of spatial structure can impair the management of a species at a variety of temporal scales. Disregarding spatial structure may result in incorrectly assessing population status or misunderstanding the response to habitat restoration (Cooper & Mangel 1999). For instance, some areas in high abundance may actually be production sinks where as other areas with lower fish abundance may be responsible for most of the production (Pulliman 1988). At longer time scales, the relationship between spatial structure, population dynamics, and the landscape may determine the degree to which populations adapt to local conditions (Sultan & Spencer 2002) and how they respond to disturbance (Picket & White 1985). Also, population structure affects genetic diversity and effective population size. Due to the demographic interplay between areas the effective population size may be smaller (or larger) than expected.

### Rationale for developing a spatial structure criterion

Knowledge of spatial structure demands familiarity with occupied and unoccupied habitat patches, patch quality, intra-patch dynamics, and dispersal rates for all life stages. Empirical data, and even anecdotal observations, pertaining to these factors for Great Basin redband trout populations are extremely limited. In most cases little or no information exists to characterize spatial structure at the population or SMU scale. However, Rieman and Dunham (2000) described probable lines of evidence describing spatial structure of other inland salmonid species, and even though data are limited in all cases, they found evidence of very different structural patterns for each species. Their findings present two points relevant to Great Basin redband trout; 1) inland trout can and do develop some semblance of complex spatial structure and 2) one generalized model does not apply to all species.

It is logical to assume spatial structure plays a role in the dynamics of redband trout populations, especially considering that spatial structure may be a continuum of processes acting on a variety of spatial and temporal scales (Rieman and Dunham 2000). For instance 'mainland-island' or 'source-sink' metapopulation models may describe the mechanism by which the theorized expansion and contraction of populations occurs over wet and dry cycles. During dry years subpopulations occupying ephemeral habitat may nearly or completely go extinct, where only large subpopulations in high quality patches persist. During wet years the subpopulations that persisted then act as a source to re-colonize patches whose suitability is dependent on water year. Due to variation in patch quality, some subpopulations may be relatively prone to extinction during low water years compared to larger subpopulations in high quality habitats. The largest subpopulations, 'mainland' or 'source' populations, are the key to persistence whereas the smaller, 'island' or 'sink' patches have relatively high rates of local extinction and depend on re-colonization from the mainland populations. Other models may also be pertinent at this and other temporal and spatial scales.

Given that little information is available on how spatial structure relates to salmonid viability in general (McElhany et al. 2000) and biologists are unable to describe the spatial structure of redband trout populations specifically, this plan has developed a composite metric to assess the <u>potential</u> for a complex structure to exist. The intent is to identify and conserve processes, such as dispersal, life history, and linkages between landscapes that likely contribute to persistence regardless of the actual spatial structure (Rieman and Dunham 2000). Thus, by nature, the metric considers landscape scale processes as opposed to empirical population specific data. This plan assumes historical populations survived many years of environmental change and therefore must have had adequate structure and diversity to remain persistent. Therefore, when managing for persistence and viability the goal is to preserve elements of historical spatial processes since it is not known whether a novel structure is sustainable (sensu McElhany et al. 2000).

The viability criterion for spatial structure evaluates two components separately, habitat availability/suitability and connectivity. Each component is comprised of 2 or 3 metrics assessing different facets of that component. The metrics are scored on a continuum where large, connected, populations in suitable habitats are assumed to be persistent and those that are small, isolated, and in degraded habitats are at some risk of extinction (Dunham and Rieman 1999). Additional factors exist that are not employed here but equally relevant to those included in this assessment. For example other plans and assessments of anadromous salmonids include a metric that assesses the distance between spawning areas (ICTRT 2007) as an indicator of impacts on gene flow. Trout Unlimited's CSI incorporates road density and 303d listed streams as indicators of watershed condition (Williams et al. 2007). However data relevant to such metrics for Great Basin redband trout either are not available or do not have the level of resolution necessary for a consistent across the board assessment. As additional data and information become available the metric may be changed, either in regard to the subcomponents, scoring, or the design.

**Spatial structure metric**

**Goal –**To manage the physical habitat template to conserve and restore natural spatially mediated processes in order to maintain population level diversity and viability.

**Objective 1.** – Maintain natural distribution through habitat availability

**A. Habitat Quantity –**
This metric provides a measure of how much historically available habitat is currently occupied. Following the guidelines provided by McElhany et al. (2000) the goal is to maintain the historical template of available habitat and ensure habitat patches are not destroyed faster than they are

naturally created. Thus populations whose current distribution is equivalent to historical distribution are considered to be at very low risk of not being viable, whereas populations occupying less than 50% of the historical distribution are at high risk.

The challenge provided by this metric is that historical distribution of redband trout is virtually undocumented and therefore unknowable (Schill 2009). In the absence of a definitive measure of historical (pre-settlement) distribution other assessments for interior trout have relied on the designation of perennial streams as representative of historical distribution (Williams et al 2007). This is a logical and very reasonable approach, however the classification of perennial streams in the Malheur Lakes basin (USGS 2010) is disjunct and does not corroborate on the ground observations, providing little confidence in the interpretation. As an alternative, this plan assumes the current upper extent of redband trout is similar to that historically and historical distribution includes all natural connected downstream reaches to the lakes or points of dissipation. While not a perfect measure, this approach provides a general estimate adequate to assess large scale changes in distribution and habitat use and, hence, risk.

**Table A2-4 Metric - Percent of historical distribution currently occupied**

| % stream distance | Risk | Score |
|---|---|---|
| > 90% | Very Low | 5 |
| 75-89 % | Low | 4 |
| 50-74 % | Moderate | 3 |
| <50% | High | 1 |

**B. Habitat Quality**

Habitat condition is of fundamental importance to the persistence of Great Basin redband trout populations. High quality habitat buffers extreme conditions and tempers the effects of environmental variation. Populations with adequate, well-connected, and well-distributed refuge habitat are poised to respond quickly to improving conditions, increasing the probability that distribution and abundance will quickly rebound. Populations that persist in degraded habitat may also rebound after short term perturbations, but may not be able to re-colonize unoccupied habitat or attain prior levels of abundance. In the context of spatial structure, good watershed condition (i.e. lacking significant anthropogenic impacts), increases the likelihood there is spatial connectivity between stream reaches and subbasins that retain habitat attributes which reflect historic conditions. Populations and subpopulations impacted by significant habitat degradation have likely experienced decreases in productivity and carrying capacity, which in turn can impair fish dispersal and intra-population dynamics.

High quality habitat is a critical factor for the persistence of a species, but specific parameters that define good habitat for high desert populations of redband trout remain elusive. Various studies have identified elevation, gradient, complex pools, riparian shade and the distance from headwaters as factors that explain the abundance of redband trout in Idaho and British Columbia (Muhlfeld et al. 2001, Zoellick and Cade 2006). Local occurrence of Lahontan cutthroat trout, another trout species inhabiting high elevation desert streams, has been explained by maximum stream temperature, stream gradient, connectivity to migratory habitats and the presence of non-native species (Dunham et al 1999, Dunham et al 2002, Dunham et al 2003). However the applicability of these parameters and their associated models are difficult to extrapolate to other basins and regions given the diversity of habitat occupied by redband trout and the specificity of each model (Faucsh et al. 1988, Dambacher et al 2009). Though specific variables have not been identified for Great Basin redband trout it is generally accepted that temperature and stream flow, or their surrogate variables, are of primary importance (sensu Zoellick and Cade 2006). The technical committee also has emphasized the significance of stream habitat complexity, bank stability, and riparian condition.

Assessing habitat quality and watershed condition for Great Basin redband trout presents a number of challenges. First, data are lacking to adequately evaluate habitat condition in all populations. Datasets of in-stream habitat variables exist for Malheur Lakes streams, but each dataset has limitations. They are either greater than 10 years old and not indicative of current condition, not representative at the population scale or do not include a comprehensive set of habitat variables. Second, redband trout are found in a wide variety of habitats, and it is not clear which specific habitat features are critical to population persistence. Intuitively, water temperature, stream flow, and measures of habitat structure (e.g. number of deep pools or wood volume) comprise the foundation of suitable habitat for redband trout, but metrics describing the condition of these factors have limited value for a habitat risk assessment for redband trout without a greater understanding of the critical biological thresholds for these factors.

When developing a singular habitat quality metric, the redband trout technical committee deliberately chose not to employ a subjective measure based on best professional opinion, for two reasons. First, a subjective measure would lack consistency between professionals where ratings given by various biologists may differ based on experience and background. Second, the area to be evaluated is so vast, no one biologist had comprehensive familiarity with all populations or stream reaches. As a result, a consistent application of a subjective rating system between streams and populations would not be achievable.

Similarly the committee avoided using proxy measures, such as the percent of the watershed converted to agricultural uses, road density, or the number of miles of irrigation canals, that have been applied in assessments of other interior trout species (Shepard et al. 2005, Williams et al. 2007). In the case of Oregon's redband trout populations, such surrogate variables were found to be broad scale, indirect, and required unsupported assumptions.

For this plan, the Planning Team is proposing that habitat quality be assessed with a limiting factors habitat model, HabRate, which was developed by ODFW Aquatic Inventory Project to assess potential quality of in-stream habitat for steelhead trout (Burke et al. 2010). HabRate is a logic based model that evaluates sites based on their suitability for each life history stage (spawning to emergence, 0+ summer rearing, 0+ overwintering, 1+ summer rearing and 1+ overwintering). It incorporates a collection of stream level variables that describe limiting factors into a series of 'if-then' statements. Model output provides a general habitat rating of good, fair, or poor for each life history stage at each site. A comprehensive literature review of steelhead habitat requirements provided the basis for criteria included in the model (Burke et al. 2010). While the model was designed specifically for steelhead trout in the Deschutes River Basin it was intended to be applicable to basins of the Pacific Northwest. Given the depth of the literature review, the lack of redband trout specific studies, and the use of diverse habitat by redband trout, the criteria as written for Deschutes Basin steelhead trout were considered the best starting point for Great Basin redband trout. Future research concerning specific habitat needs should be incorporated into the model when available.

HabRate appears to be well suited for Great Basin redband trout and is best evaluated by an analysis of a dataset that contains measures of both trout abundance and habitat variables for each sample site

(Dambacher et al 2009). Here age 1+ fish densities (fish/10m) were consistently highest for sites rated as 'good' and lowest for those rated as 'poor' (Fig. 2) for both age 0+ summer and winter rearing criteria. Differences between sites rated as high, fair and poor were significant (ANOVA, summer: F = 7.06, p = 0.001. Winter: F=11.25, p<0.0001).

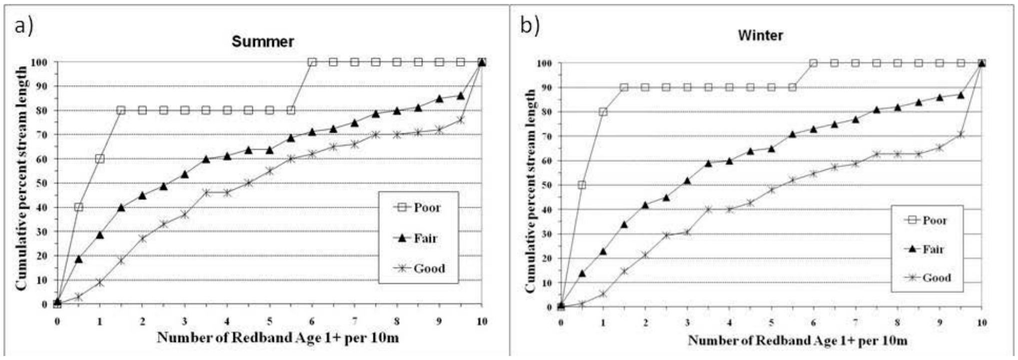


Figure A2-2. Cumulative distribution function of redband trout density for sites HabRate scored as 'good', 'fair' or 'poor' for age 0+ A) summer and B) winter rearing habitat.

Results of the HabRate analysis provides a rating of 'good', 'fair', or 'poor' for each of the five life stages at each site. A habitat assessment incorporates spawning/emergence, 0+ summer, and 0+ winter rearing scores into a final habitat score. A population is then rated given the percentage of sites that were described as a certain condition.

**Table A2-5 Metric – Percentage of habitat rated as in good, fair or poor condition based on the outcome of the HabRate model.**

| Good | Fair | Poor | Score | Risk |
|---|---|---|---|---|
| 90-100% | Up to 10 % combine | | 5 | Very Low |
| > 50% | < 50% combine | | 4 | Low |
| | > 70% | < 30% | 3 | Moderate |
| | < 70% | > 30% | 1 | High |

**C. Habitat Arrangement**

Dendritic stream networks can have a fundamental impact on the spatial structure of a population as determined by habitat distribution and connectivity. Relative to linear systems, the stream network of a highly dendritic system is comprised of a greater proportion of low order streams. This distribution of headwater streams increases the potential for multiple spawning areas (patches) within a population, hence increasing diversity and spreading the risk of extinction due to stochastic events (sensu ICTRT 2007). The dendritic pattern of rivers has also been shown to have sometimes profound effects on extinction risk (Fagan 2002) and connectivity between habitats patches (Rieman and Dunham 2000). This metric addresses the inherent risk to the population associated with its natural configuration.

**Table A2-6 Metric – spatial arrangement of habitat patches.**

**Scoring**

| Stream Order | # of Junctions | Risk | Score |
|---|---|---|---|
| > 5 | > 5 - Dendritic | very low | 5 |

| | | | |
|---|---|---|---|
| 4 | 3-4 | low | 4 |
| 3 | 1-2 | moderate | 3 |
| 1 - 2 | 0 (linear) | high | 1 |

**2. Objective - Maintain historical levels of connectivity**

**A. Accessible migratory corridors**
Maintaining migratory corridors free from obstruction is a critical step in maintaining historical levels of connectivity. Natural rates of movement between subpopulations should not be substantially altered by human actions (McElhany et al. 2000). Barriers, or even partial barriers, change movement patterns and alter dispersal rates (Anderson 2009), which can potentially affect the long term persistence of a population. For Great Basin redband trout irrigation structures, such as push up dams and irrigation weirs, are common impediments to migration. In addition, poor water quality, unscreened diversions and poorly constructed road culverts also impact movement patterns. Ideally this conservation plan could directly assess the impact of barriers to migratory behavior. Unfortunately the number and location of many impediments to passage are undocumented largely due to lack of access to private property. Thus, a representative measure is employed where the distance of current migratory corridors is compared to that historically. The longest continuous stream segment uninterrupted by a known barrier is the unit of comparison and serves to represent connectivity within the entire basin. Populations in which the difference is greater than 50% are considered at high risk of not maintaining the historical template of connectivity. It is important to note this metric is based on known barriers. Effects of suspected (e.g. water quality) or unidentified (e.g. undocumented irrigation dams) barriers is listed as a research need.

**Table A2-7 Metric - Percent of current greatest continuous stream distance (i.e. w/o barriers) relative to historical.**

| % of stream | Risk | Score |
|---|---|---|
| > 90% | Very Low | 5 |
| 75-89 % | Low | 4 |
| 50-74 % | Moderate | 3 |
| <50% | High | 1 |

**B. Potential for migratory behavior**
Additionally, life history type affects dispersal rates where populations that express a migratory life history are more likely to move between suitable patches than populations that contain only small resident fish. Populations that have access to large water bodies capable of fostering the growth of large fish have a high potential of expressing a migratory life history. These habitats are primarily lakes and large rivers. Maintaining these habitats in places where they were historically present preserves the potential for retaining the historical spatial structure of a population. Populations are rated on the availability of large rearing habitat. The intent of this metric is simply to evaluate if habitat is available to foster a migratory life history. In some instances habitat may be available but is not usable 100% of the year, every year, or is inhospitable (e.g. occupied by carp). In cases where the quality of these habitats is compromised, risk to these populations is upgraded until habitat improvements create more hospitable conditions. Reservoirs, human created lakes, and impoundments are not considered as potential habitats for this evaluation.

**Table A2-8 Metric – Migratory adult rearing habitat available**

| Availability | Risk | Score |
|---|---|---|
| Available | Very Low | 5 |
| Available but not habitable or assessable year around | Moderate | 3 |
| Not Available | High | 1 |

**Spatial Structure Scoring –**
A mean score is calculated for each component of the spatial structure criterion, Habitat (1.A, 1.B, and 1.C) and Migratory potential (2.A and 2.B). Given spatial structure is indicated by both habitat connectivity and watershed condition and without either component spatial structure may be compromised, the lowest (highest risk) of the two mean scores is used as the overall score for spatial structure.

**Diversity**

Incorporating a diversity criterion into an assessment of viability helps ensure the preservation of the underlying genetic resources necessary for a population to fully exploit existing ecological opportunities, adapt to future environmental changes, or simply maintain a sustainable status (WLCTRT 2006). The emphasis on preservation is significant because once lost genetic variation is effectively gone forever (Riddell 1993).
Diversity is described as the distribution of traits within and among populations. These traits are defined as both genotypes and phenotypes that range in scale from single genes to complex life-history traits (McElhany et al 2000). The genotype is the hardwired genetic code of an organism, essentially the instructions contained in the DNA. A population of individuals with low genotypic diversity has very little variation in the genetic makeup among all fish. This is often typical of small and isolated populations. An individual's phenotype refers to the observable expression of an organism's genetic code such as body shape, disease resistance, or age at maturity. The phenotype is the result of an organism's genotype as well as the influence of environmental factors and the interaction of the two. As a result the phenotype is considered more plastic (variable) than the genotype. Pink salmon is an example of a species with low phenotypic variation in which every population returns to their natal stream every two years. There is very little or no variation in age at maturity among individuals or populations.

The degree of genotypic and phenotypic diversity can have a profound effect on population persistence and viability in the face of environmental change. A population with a highly diverse array of genotypes has a large capacity to respond to environmental variability which in turn buffers the population against short term spatial and temporal changes in conditions. Similarly, variation, particularly phenotypic variance, is expected to be high for populations occupying uncertain and unpredictable environments (Li et al. 2007). A highly diverse population can also exploit a wide variety of environmental and habitat conditions (McElhany et al. 2000). On larger scales, populations rich in genetic diversity have the necessary raw material for surviving long term change (McElhany et al 2000). Ultimately, naturally diverse populations may have more stable dynamics, and hence be more viable in changing environments than less diverse populations (Rieman and Dunham 2000).

Redband trout are often characterized as being highly diverse, to such a degree that no common trait can be used to define the species or explain their evolutionary history as a whole (Behnke 1992, 2002). Within the Oregon portion of the Great Basin alone, redband trout comprise at least three genetic races, where populations in the Goose Lake, Warner Lakes and Chewaucan are most similar to each other and those from the Sacramento River complex, populations in the Malheur Lakes and Fort Rock are most closely related to those in the Columbia River, and the Upper Klamath Lake populations are distinctly different from the others (Currens et al. 2009). Significant levels of genetic variation have also been documented within populations. Multiple studies found genetic differences between tributaries within the same hydrologic basin (Small et al. 2007 Matala et al. 2008, Knudsen et al 2002 and Dehaan and Adams 2009). However, as expected, small isolated populations show lower levels of genetic diversity than interconnected populations (Currens et al. 2009, Dehaan and Adams 2009).

As mentioned prior, highly diverse populations have the capacity to adapt to a variety of conditions and are able to successfully respond to changes in their environment. This was the case for Goose Lake redband trout during extreme drought years, 1926 and 1992, when Goose Lake dried and favorable stream habitat conditions dwindled (Li et al. 2007, Federal Register 2000). The adfluvial life history disappeared during these dry periods, but stream resident forms persisted in the small tributaries. When wetter conditions returned after the drought populations were able to (re)express an adfluvial life history (Tinniswood 2007). Populations with limited diversity may be constrained in their ability to exist as a solely resident population or re-establish a migratory life history after such extreme changes in environmental conditions.

Noted as being particularly plastic, redband trout as a species has optimally exploited a wide variety of habitats. A classic example is in spring fed systems, such as the Metolius River and Spring Creek in the Upper Klamath Lake basin, where annual fluctuations in water temperature and flow are minimal, redband trout have been observed spawning ten months of the year, whereas trout in other populations spawn only a few months in the spring when water temperature and flows are adequate (ODFW unpublished data, Li et al. 2007, Schroeder 2007). This variation in spawn timing allows redband trout to exploit favorable spawning conditions directly resulting in increased productivity and potential for persistence.

**Rationale for developing a diversity criterion**

The role of diversity in the persistence and viability of redband trout populations is complex and uncertain. Biologists recognize the importance of diversity and the subtle (and not so subtle) ways in which it can affect the long-term viability of population or species (McElhany et al. 2000, WLCTRT 2006). And it is well understood that redband trout populations throughout the Great Basin are highly diverse, both genetically and phenotypically (Li et al. 2007, Gamperl et al. 2002, Currens et al. 2009). However uncertainties arise regarding methods to assess diversity and then determining how much diversity is enough to attain population persistence, especially in dynamic environments occupied by redband trout. To address the later this conservation plan relies on the historical template to provide the benchmark for current levels of diversity. It assumes that historical redband trout populations were sustainable and therefore preserving historical levels of diversity (to the best of our knowledge) ensures adequate diversity for current populations to remain sustainable (McElhany et al. 2000). Thus the challenge that remains is the former, developing a measure to consistently quantify and assess population level diversity.

Diversity can be measured either directly or indirectly. Direct measures involve observations of the variation in specific life history traits, i.e. the products of natural selection such as variation in run time and or size at maturation. Indirect measures consider the external factors or processes that influence their underlying genetic components or their phenotypic expression such as effective population size or spatial distribution. Counter-intuitively, genetic analyses are considered an indirect measure of diversity given they examine the distribution of neutral genetic markers within a population and not necessarily the genes upon which selective forces interact.

Ideally this conservation plan would incorporate direct measures of diversity to assess viability; however specific traits of redband trout life history remain unknown. Minimally biologists may be able to identify major life history types within a population but the possibility of evaluating traits of which those types are comprised, e.g. run timing or age at maturity, has yet to be attained. To address the shortcomings of direct measures of diversity for Great Basin redband trout specifically, this conservation plan uses two metrics to assess diversity, the presence of multiple life history types, and an indirect measure of ecological diversity. The intent is that the direct measure confirms a substantial degree of diversity, and that the indirect ecological measure will be representative of a finer examination when data regarding life history types are unavailable or uncertain.

A genetic evaluation that details population level diversity was completed in 2015. Redband trout within the Great Basin, including Malheur Lakes SMU, had less genetic diversity than populations having connections to large rivers such as the Columbia or Snake rivers (Dehaan and Von Bargen 2015). Populations of redband trout within the Great Basin with connections to lakes had higher genetic diversity and effective population size ($N_e$) relative to other populations within that geographic area (Dehaan and VonBargen 2015). Introgression with hatchery rainbow trout (coastal) in the Malheur Lakes SMU is low with Silver Creek having higher introgression relative to other populations within the SMU (Dehaan and Von Bargen 2015).

**Diversity**

**Goal –** Preserve phenotypic diversity as determined by spatially mediated processes such that the adaptive potential of genetic diversity is preserved through long term environmental change.

**1. Objective – Maintain life-history expression by maintaining known attributes of life history types**

For Great Basin redband trout in particular fine details describing the extent of life history variation are unknown. In most populations data specific to phenotypic traits (e.g. spawn timing and age structure) have yet to be collected. In fact, in most populations just the identification of simply a migratory or resident life history is the extent to which life history variation can be described. Therefore the application of this metric reflects the level of resolution to which biologists can describe life history strategies expressed by a population. This plan assumes every population expresses a resident life history strategy at a minimum. The presence of a migratory component is indicated by relatively large individuals or evidence of migratory behavior within the past 6 – 7 years (2 generations). Given the resolution of these data, this metric can only provide two risk categories. When more detailed life history data are available, then additional risk categories will be incorporated.

**Table A2-9 Metric – Life history diversity**

| Life history | Risk | Score |
|---|---|---|

| | | |
|---|---|---|
| Multiple Life Histories | Very Low | 5 |
| Resident Only | Moderate | 3 |

**2. Objective –** Maintain life-history expression by maintaining occupancy in a natural variety of available habitat types where a diversity of spatially-mediated processes occur.

Diversity within a population is closely related to habitat diversity; where salmonid populations exhibit local adaptation to specific habitats they occupy (Crossin et al. 2004). As a result variation in habitat types promotes the expression of a variety of phenotypes (Hendry et al 1998, Waples et al. 2001). Therefore, in theory, the greater the variation among available habitats the higher the probability for phenotypic and genotypic variation within a population (Neville et al. 2009). Significant changes in habitat conditions can affect life history or morphological diversity within a population (Frissell 1986).

Given the absence of quantified data describing habitat scale variation and the lack of any known thresholds at which loss in ecological diversity reduces genetic diversity (WLCTRT 2006), this plan relies on elevation categories to identify different habitat types encountered within the distribution of each population (sensu WLCTRT 2006). Habitats within elevation categories are generally distinguished by stream order, gradient, and thermal regimes, all factors influencing local adaptation. This landscape scale evaluation serves as a proxy for ecological diversity that may occur within a population due to differences in habitat conditions. To quantify reductions in diversity comparisons are made between current and historical distribution of fishes within each elevation band. The metric calculates the average absolute change in proportion between current and historical distribution within each category. Note that the scoring of this metric does not detect the magnitude of habitat loss as in the spatial structure metrics, simply the distribution of that loss.

**Table A2-10 Metric – Average cumulative % change in occupancy across elevation bands.**

| % Change | Risk | Score |
|---|---|---|
| < 5% | Very Low | 5 |
| 6 - 10% | Low | 4 |
| 11 - 20% | Moderate | 3 |
| > 20% | High | 1 |

**Diversity Scoring –**

The final diversity score is calculated as the mean of the two metrics. This approach equally weights the two metrics and speaks to the significantly different aspects of diversity that each measures.

**Viability**

The scores for the four viability parameters are combine to generate an overall rating of risk for each population. The mean is calculated for abundance and productivity (A/P), as is the mean for spatial structure and diversity (SS/D). The mean scores are then rated according to the matrix below. For all intents and purposes the combine A/P and SS/D scores are weighted equally and the final score tends to default to that of highest risk. For many salmon viability assessments, the A/P score is given greater emphasis in the final risk rating for a specific population. This approach could also be applied to redband trout given the empirical nature of the A/P estimates. However, for redband trout SS/D are likely equally, if not more, important than A/P as they relate to population viability, and are therefore equally weighted.

**Table A2-11**

**Spatial Structure & Diversity** (mean of the two scores)

**A/P** (mean of the two scores)

| **Risk** | **Very Low (5)** | **Low (4)** | **Moderate (3)** | **High (1)** |
|---|---|---|---|---|
| **Very low (5)** | Very Low | Low | Moderate | Moderate |
| **Low (4)** | Low | Low | Moderate | High |
| **Moderate (3)** | Moderate | Moderate | Moderate | High |
| **High (1)** | Moderate | High | High | High |

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## APPENDIX 3

## POPULATION-SPECIFIC LIMITING FACTORS AND THREATS

## Threats and Associated Limiting Factors for Malheur Lakes Redband Trout Populations

The key and secondary limiting factors and threats that contribute to the current status of redband trout populations in the Malheur Lakes are shown in Tables A3-2 through A3-14 for each population below. The codes used in all tables are described in Table A3-1.

**Table A3-1. Codes used for summarizing limiting factors and threats in Tables A3-2 – A3-14 and subsections below.**

| Code | Limiting Factor | Threat |
|---|---|---|
| 1 | Water Quantity: Decreased Stream flow | b. Water Withdrawal |
| | | c. Agriculture and Irrigation Activities |
| | | e. Grazing, Timber, & Riparian Management Practices |
| 1 | Water Quantity: Altered Hydrograph | h. Irrigation Practices |
| | | j. Reservoir Operations |
| 2 | Water Quality: Temperature | a. Reservoir Conditions |
| | | b. Irrigation Practices |
| | | c. Water Withdrawal |
| | | e. Grazing, Timber, & Riparian Management Practices |
| 2 | Water Quality: Chemical & Turbidity | g. Non-Point Source Pollution |
| | | j. Non-native Species: Carp, Bullhead |
| 3 | Predation | a. Non-native Species: Smallmouth Bass, Brook Trout |
| 4 | Competition | a. Non-native Species: Carp, Largemouth Bass, Brook Trout |
| 6 | Physical Habitat: Degradation | b. Channelization |
| | | c. Water Withdrawal |
| | | f. Grazing, Timber, & Riparian Management Practices |
| | | g. Recreation |
| | | h. Juniper Encroachment |
| | | l. Road Construction - Channel Confinement |
| 6 | Physical Habitat: Siltation | d. Grazing, Timber, & Riparian Management Practices |
| | | e. Forest Roads |
| 7 | Habitat Access | a. Dams and Diversions |
| | | b. Culvert Crossings |
| 8 | Other Factors | b. No Agency Access |

**A3.1 Factors and threats limiting viability of Silver Creek redband trout**

**Table A3-2. Key and secondary limiting factors of the Silver Creek redband trout population. Bolded and shaded codes are key concerns and non-bolded/shaded codes are secondary concerns.**

<table>
<tr><th rowspan="2">Threat</th><th colspan="5">Headwater / Tributary</th><th colspan="2">Large River / Lake</th></tr>
<tr><th>egg</th><th>juvenile</th><th>resident sub-adult</th><th>resident adult</th><th>spawner</th><th>migratory sub-adult</th><th>migratory adult</th></tr>
<tr><td>Water Management</td><td></td><td></td><td></td><td></td><td></td><td colspan="2">1b, 2c, 6c, 7a</td></tr>
<tr><td rowspan="2">Land Management</td><td colspan="2">6d, 6e</td><td></td><td></td><td>6d, 6e</td><td colspan="2" rowspan="2">1c, 2e, 6d, 6f</td></tr>
<tr><td colspan="5">1e, 2e, 6f, 7b</td></tr>
<tr><td>Introduced Species</td><td colspan="5"></td><td colspan="2">2j, 4a</td></tr>
<tr><td>Hatchery</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Harvest</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

The greatest threats to redband trout in the Silver Creek basin were generated from intense land-use beginning in the late 1800s. Over one hundred years of timber harvest, beaver trapping, and livestock grazing have impaired historical watershed processes and significantly altered the condition and function of in-stream habitats. Although timber, agriculture, and grazing practices are vastly improved over those employed historically (pre 1980's) stream habitats in many locations are still being impacted and others are slow to recover leaving redband trout vulnerable to elements of risk.

<u>Water Quantity</u>

The timing and magnitude of flows in the Silver Creek basin are not representative of the historical hydrograph. Watershed conditions have altered the system's ability to capture, store and slowly release water year around. As a result flows are fast and flashy during precipitation events (HCWC 2000a). During dry months stream flows are often inadequate, unable to provide sufficient habitat for aquatic species while meeting the demand for anthropogenic water use. Insufficient stream flow, particularly in the summer months, has been identified as a significant concern in the lower sections of Silver Creek below the confluence of Nicoll Creek, as well as in the headwater tributary streams of Claw, Stone Corral (WNTI 2012), Dodson, Upper Silver, Delintment and Wickiup Creeks (USFS 2010). In addition, the entire basin, except Rough Creek, is ranked highest in need of flow restoration (OWRD and ODFW 2002).

*Water Management*

(1b) - Water Withdrawal

| Rank: | Key | Geographic Area: | Large River / Lake | Life Stage: | Migratory adult & sub-adult |
|---|---|---|---|---|---|

Withdrawal of water at irrigation diversions decreases overall water volume and in-stream flow. The lower flows result in reduced habitat and increases in water temperature directly impacting migratory fish that may use the main channel for migration and rearing purposes. Operation of diversions on Silver Creek near the confluence of Dairy and Wickiup Creeks and downstream of Nicoll Creek are of particular concern.

*Land Management*

(1c) – Agriculture and Irrigation Activities

| Rank: | Key | Geographic Area: | Large River / Lake | Life Stage: | Migratory adult & sub-adult |
|---|---|---|---|---|---|

Most water use in the Silver Creek basin is for agricultural purposes, primarily through irrigation (HCWC 2000a). Groundwater take by pivot irrigation operations in Silver Creek Valley lowers the water table and reduces surface flow particularly in the summer and fall when run off has subsided. The decrease in flow directly impacts the migratory life stages that would typically use the mainstem of Silver Creek for rearing and migration.

(1e) – Grazing, Timber and Riparian Management Practices

| Rank: | Key | Geographic Area: | Headwater / Tributary | Life Stage: | all resident life stages |
|---|---|---|---|---|---|

Legacy impacts of historical grazing and timber activities have resulted in an overall decrease of in-stream flow in the headwaters and many of the tributaries of Silver Creek basin, particularly Lower Wickiup, Delintment, Upper Silver and Dodson Creeks (USFS 2010). Historical land use impacts have interrupted natural watershed processes and reduced the system's capacity to retain and slowly release water throughout the water year. The removal of vegetation in the uplands and associated soil compaction has reduced infiltration rates during precipitation events. Increased overland flow and degraded riparian areas create high and fast flows and a flashy hydrograph. In addition, formerly hydric soils are now drained and the lack of infiltration does not fully recharge the water table resulting in low flows and dry channels in the summer and drought periods (based on Technical Team input). The decrease in flow and water volume impacts all life stages residing in these streams.

Water Quality

Silver Creek and many of its tributaries are included on Oregon Department of Environmental Quality's (ODEQ) 303(d) list of impaired waterways. Silver, Wickiup, Sawmill, Claw, and Nicoll creeks are all streams occupied by redband trout that exceed the temperature thresholds recommended by ODEQ (ODEQ 2010). Egypt and Salt Canyon creeks, streams historically occupied by redband trout (WNTI 2012), are also listed.

*Water Management*

(2c) - Water Withdrawal

| Rank: | Key | Geographic Area: | Large River / Lake | Life Stage: | Migratory adult & sub-adult |
|---|---|---|---|---|---|

The withdrawal of water at diversions on mainstem Silver Creek, Wickiup Creek, and Dairy Creek contribute to elevated stream temperatures and decreased dissolved oxygen levels. Low water volume is highly susceptible to increases in water temperature. Low flows are also susceptible to stagnation, further exacerbating low dissolved oxygen levels. These low flow and warm water conditions create inhospitable conditions for redband trout in the summer months

*Land Management*

(2e) - Grazing, Timber and Riparian Management Practices

| Rank: | Key | Geographic Area: | Large River & Tributary | Life Stage: | All |
|---|---|---|---|---|---|

The removal and degradation of riparian vegetation and associated streamside shading increases the exposure of the water's surface to solar radiation contributing to elevated in-stream water temperatures. Of particular concern are Silver Creek reaches downstream of the confluence with Nicoll Creek, and Short, Upper Wickiup, Dairy, Nicoll and Upper Silver creeks (WNTI 2012, based on Technical Team input, USFS 2010).

*Introduced Species*

(2j) – Non-native Species: Common Carp and Brown Bullhead

| Rank: | Secondary | Geographic Area: | Large River / Lake | Life Stage: | Migratory adult & sub-adult |
|---|---|---|---|---|---|

Introduced species in Moon Reservoir, particularly common carp and brown bullhead, negatively impact water quality for rearing migratory adults. Both carp and bullhead are bottom feeders typically rooting in the substrate for macroinvertebrate prey. Constant digging activity suspends sediments and uproots vegetation. As visual predators, redband trout suffer reduced feeding success and higher physiological stress in turbid conditions.

<u>Competition</u>

*Introduced Species*

(4a) – Non-native Species

| Rank: | Secondary | Geographic Area: | Large River / Lake | Life Stage: | Migratory adult & sub-adult |
|---|---|---|---|---|---|

Common carp, largemouth bass, white crappie, and brown bullhead in Moon Reservoir and in the lowest reaches of Silver Creek compete with redband trout for food and space, reducing potential growth for adult rearing redband trout. These non-native warm water species likely have a competitive advantage over redband trout given they are better adapted to the warm water temperatures and the habitat conditions.

<u>Physical Habitat Quality</u>

In-stream physical habitat quality in Silver Creek basin is notably degraded relative to what is considered historical condition (USFS 1998). Almost all land management activities (including timber harvest, livestock grazing, fire suppression and beaver trapping) implemented in the past 50-100 years have impacted in-stream habitat quality and channel complexity through the removal and degradation of riparian and upland vegetation. The resulting channel incision and erosion has reduced complexity and disconnected streams from off channel habitats, secondary channels and the floodplain (USFS 1998). In 1964 a 100 year rain-on-snow event came at a time when many of the floodplains were primarily exposed dirt and the epic flood channelized most of the streams in the basin (USFS 1998, HCWC 2000a). Since then multiple habitat restoration actions have been implemented, but degraded habitat conditions persist in many streams continuing to put redband trout at risk (USFS 1998, WNTI 2012). Today, much of the Silver Creek basin is characterized by over simplified in-stream habitat and excessive sedimentation (USFS 1998, HCWC 2000a, WNTI 2012).

*Water Management*

(6c)- Water Withdrawal

| Rank: | Key | Geographic Area: | Large River | Life Stage: | Migratory adult & sub-adult |
|---|---|---|---|---|---|

The withdrawal of water at diversions in the mainstem of Silver Creek reduces the volume of available habitat for rearing and migration, significantly reducing the potential density and biomass of migratory redband trout. In addition, low water volume also hinders hydrologic channel forming processes that create pools, riffles and other habitat types.

*Land Management*

(6d) – Grazing, Timber and Riparian Management Practices – Sediment Input

| Rank: | Key | Geographic Area: | Large River & Tributary | Life Stage: | All |
|---|---|---|---|---|---|

Current and historical livestock grazing and timber harvest activities and their long term impacts have contributed to increased sediment input. The Western Native Trout Initiative (WNTI) Range-wide Redband Trout Assessment (2012) identifies excessive sedimentation as an issue in all tributaries upstream of Dodson Creek (including Dodson Creek), all streams in Nicoll Creek, most stream reaches in Wickiup Creek, and in lower Silver Creek. Fine sediment that fills the interstitial spaces potentially suffocates eggs, degrades spawning habitat, embeds substrates and eliminates cover for fry. Sedimentation most dramatically impacts redband trout during spawning, egg incubation and rearing of fry and small juveniles. In particular soil types extreme sedimentation could also affect turbidity and water quality impacting redband trout ability to hunt and respire.

(6e) – High Density Forest Roads

| Rank: | Key | Geographic Area: | Headwater / Tributary | Life Stage: | Eggs, juveniles & spawners |
|---|---|---|---|---|---|

High density forest roads are present in headwater tributaries of Silver Creek on US Forest Service (USFS) property, particularly in, but not limited to, Upper Silver, Upper Wickiup, Sawmill and Rough creeks. Improperly located or maintained forest roads increase run-off and sedimentation of in-stream substrates. Embedded gravels and substrates reduce habitat complexity particularly for spawning adults, incubating eggs and all stages of fry & fingerlings. The USFS is working on decommissioning roads, but there is a significant amount of resistance to this from the local public.

(6f) – Grazing, Timber and Riparian Management Practices - Degradation

| Rank: | Key | Geographic Area: | Large River & Tributary | Life Stage: | All |
|---|---|---|---|---|---|

Current and historical grazing and timber activity in the upper portion of the Silver Creek basin has resulted in a loss of habitat complexity and degraded in-stream conditions. Down cutting of the streambed has incised the channel and disconnected it from the floodplain. As a result redband trout have lost access to braided channels and off channel habitat. The resulting down cutting and bank destabilization has simplified the habitat and degraded the riparian community. The technical committee identified the lack of significant pool habitat (both in frequency and complexity) and lack of large wood in many of the tributaries as factors significantly impacting physical habitat quality. The WNTI Range-wide Redband Trout Assessment (2012) noted a lack of pool or resting habitat in all tributaries upstream of Dodson Creek (including Dodson Creek), all streams in the Nicoll Creek basin and most stream reaches in Wickiup Creek.

Habitat Access

*Water Management*

(7a) – Dams and Diversions

| Rank: | Key | Geographic Area: | Large River / Lake | Life Stage: | Migratory adult & sub-adult |
|---|---|---|---|---|---|

Habitat access is impeded by impassable barriers on the mainstem Silver Creek. A diversion on Diary Creek is not passable and passage at most other diversions is unknown (ODFW 2012). These water diversions prevent upstream passage by migratory adults. Diversions which are unscreened may also entrain juvenile and sub-adult fish moving downstream into the irrigation system particularly during high spring flows.

*Land Management*

(7b) – Culvert Crossings

| Rank: | secondary | Geographic Area: | Headwater streams | Life Stage: | Migratory adults |
|---|---|---|---|---|---|

Improperly placed culverts used for forest road crossings create barriers to fish migrating upstream. Problem culverts are either placed far enough above the streambed that fish cannot jump the distance required to access the culvert opening or installed at an angle steep enough to create a velocity barrier. These culverts prevent access to upstream spawning and rearing habitat. Forest roads and associated culverts are most pervasive on US Forest Service property, particularly Sawmill, Rough and Upper Silver Creek (USFS 2010), however the passage status of many of these culverts is unknown. The ODFW barrier dataset lists seven culverts on Wickiup, Rough and Dairy creeks with an unknown passage status (ODFW 2012).

**A3.2 Factors and threats limiting viability of Silvies River redband trout**

**Table A3-3. Key and secondary limiting factors of the Silvies River redband trout population. Bolded and shaded codes are key concerns and non-bolded/shaded codes are secondary concerns.**

| Threat | Headwater / Tributary | | | | | Large River / Lake | |
|---|---|---|---|---|---|---|---|
| | egg | juvenile | resident sub-adult | resident adult | spawner | migratory sub-adult | migratory adult |
| Water Management | | | | | | **1b, 2b, 2c, 6b, 6c, 7a** | |
| Land Management | **6d, 6e** | | | | **6d, 6e** | **1e, 2e, 6f** | |
| | 1e, 2e, 6f, 7b | | | | | | |
| Introduced Species | | | | | | **2j,** 3a, **4a** | |
| Hatchery | | | | | | | |
| Harvest | | | | | | | |

The most significant threats to redband trout viability occur in the mainstem of the Silvies River. From Seneca to Malheur Lake the Silvies River is impaired by poor water quality and low flow issues, degraded and simplified habitats and the presence of non-native fish that compete with and prey upon redband trout. The Silvies River is an important migratory corridor and rearing habitat for migratory redband trout. The degraded conditions in the mainstem hinder trout use particularly in the summer months, potentially fragmenting the population and isolating fish residing in the tributaries. Although many of the tributary streams suffer from poor quality habitat, the cumulative limiting factors in the mainstem river and low elevation valley bottom habitats pose the greatest threat to redband trout.

Water Quantity

Flow restoration needs are ranked as high or highest in the upper Silvies basin above Trout Creek and in Emigrant Creek above Cricket Creek (OWRD and ODFW 2002). Inadequate in-stream flow, particularly in drought years, is a limiting factor in the canyon reach between the mouths of Myrtle Creek and Trout Creek (Tech Committee, WNTI 2012). In many years water does not reach Malheur Lake through the west and east forks of the Silvies River. Currently, the Silvies River contributes water to Malheur Lake only when flows exceed upstream water right allocations, usually two to three times per decade (USFWS 2012). Unnaturally low stream flows impact not only the volume of physical habitat available, but also disrupts the natural timing of the hydrograph and degrades water quality. These conditions directly affect migratory individuals who may use this portion of the river for migration, summer rearing and overwintering. Several small tributary streams in Emigrant Creek basin and in Bridge Creek (WNTI 2012) are also affected by low flows impacting the juvenile and resident adults.

*Water Management*

(1b) Water Withdrawal

| | | | | | |
|---|---|---|---|---|---|
| Rank: | Key | Geographic Area: | Large River / Lake | Life Stage: | Migratory adult & sub-adult |

Withdrawal of water at diversions interrupts the natural hydrograph by diverting and releasing water at times not historically typical. Water withdrawal also decreases overall water volume and available in-stream habitat. Water diversions occur throughout the watershed and are predominantly located above Seneca, in the Silvies River Valley, and downstream of Fivemile Dam on the East Fork of the Silvies River. Oregon Water Resources Department (OWRD) (unpublished data) has record of over 1000 points of diversion based on water rights certificates. On the ground documentation of many of these diversions has yet to be confirmed, but the record represents the degree to which water has been over appropriated in the basin (based on Technical Team input). Water withdrawal and low water quantity primarily impacts migratory trout that depend on the mainstem river for rearing and migration purposes.

*Land Management*

(1e) Grazing, Timber and Riparian Management

| Rank: | Key | Geographic Area: | Large River & Tributary | Life Stage: | All |
|---|---|---|---|---|---|

Historical and current grazing and timber management activities have negatively impacted the riparian and upland areas of the Silvies River Basin. Large scale timber operations began in the basin in the 1920s with peaks in the 1930s and 1970s (HCWC 2000b). Sheep and cattle grazing and the associated agricultural practices employed to provide winter feed for livestock have largely affected watershed process and riparian condition since the late 1800s. Uncontrolled grazing before the enactment of the Taylor Grazing Act of 1934 caused serious long-term damage (HCWC 2000b). Conditions have substantially improved since then, however some areas are still impacted and slow to recover. The combine impact of livestock grazing and timber harvest has dramatically affected watershed processes and riparian condition where precipitation quickly runs off instead of infiltrating and recharging the water table for slow release during summer months. In addition extensive beaver trapping and draining of wetlands in Bear and Silvies valleys reduces the system's capacity to capture and store water. The results are fast and flashy flows in the spring and extremely low flows in the summer and early fall. These impacts are common to both mainstem reaches and tributary basins affecting migratory and resident fish alike.

<u>Water Quality</u>

Silvies River and many of its tributaries are included on ODEQ's 303(d) list of impaired waterways (ODEQ 2010). The mainstem Silvies River is listed for exceeding temperature and dissolved oxygen criteria year around. Hay, Little Bear, Myrtle and Scotty are listed for temperatures exceeding ODEQ thresholds during the summer. In addition, there is some indication that the mainstem Silvies River has increased levels of alkalinity, phosphorous, ammonia, chloride, and pH though the river is not formally listed for these parameters. The technical committee believes the mainstem Silvies River could be a water quality barrier at Seneca during some water years, hindering access to the downstream portions of the basin for migratory fish and limiting intra-population mixing. In addition, these conditions are ideal for non-native warm water species providing them a competitive advantage over redband trout. As a result warm water conditions may exacerbate the impact of negative interactions with non-species (based on Technical Team input).

*Water Management*

(2c) Water Withdrawal

| Rank: | Key | Geographic Area: | Large River / Lake | Life Stage: | Migratory adult & sub-adult |
|---|---|---|---|---|---|

Water withdrawal at diversions within the basin contributes to elevated stream temperatures and decreased dissolved oxygen levels. Low water volume is highly susceptible to increases in water temperature during the summer months. Low flows are also susceptible to stagnation, further exacerbating low dissolved oxygen levels. These low flow and warm water conditions create inhospitable conditions for redband trout in the summer months. The technical committee identified water withdrawal as a threat to water quality in reaches downstream of Burns and in Silvies River Canyon, but also affects sections in the Silvies River Valley (WNTI 2012).

*Land Management*

(2e) Grazing, Timber and Riparian management practices

| Rank: | Key | Geographic Area: | Large River / Tributary | Life Stage: | All |
|---|---|---|---|---|---|

The removal and degradation of riparian vegetation and associated streamside shading increases the exposure of the water's surface to solar radiation ultimately contributing to elevated in-stream water temperatures. Riparian condition is an issue throughout the basin (USFS 2010), and of particular concern are reaches of the Silvies River between Myrtle Creek and Trout creek and above Seneca as well as Hall, Camp, Cricket and Spring Creeks (WNTI 2012) and Shirttail, Scotty, Hay, and Star Creeks (USFS 2010).

(2g) Non-point Source Pollution

| Rank: | Secondary | Geographic Area: | Large River / Lake | Life Stage: | Migratory adult & sub-adult |
|---|---|---|---|---|---|

Irrigation return flow and surface run-off decrease water quality through the application of chemicals associated with agriculture practices. Exposure to pesticides and herbicides has been associated with disruption of olfactory function leading to difficulty in homing, predator avoidance and finding prey (Scholz et al 2000, Tierney et al 2008). The Technical Committee identified the Silvies River below Burns and the East Fork of the Silvies River as an area of greatest concern but also for much of the mainstem river in agricultural areas of Bear Valley and Silvies River Valley.

*Introduced Species*

(2j) Non-native species

| Rank: | Key | Geographic Area: | Large River / Lake | Life Stage: | Migratory & sub-adult |
|---|---|---|---|---|---|

Common carp and brown bullheads are common in the low gradient reaches of the mainstem river up to Seneca. Brown bullheads are present at higher densities in the East Fork of the Silvies River. The foraging strategy of both species involves rooting around in soft, silty substrates, uprooting the aquatic vegetation and suspending sediments. Conditions in these areas are extremely turbid impacting the ability of redband trout to forage and respire. These conditions also negatively affect the invertebrate and piscine prey species on which redband trout forage by reducing macroinvertebrate prey densities and likely altering community composition.

<u>Predation</u>

*Introduced Species*

(3a) – Non-native Fish Species

| Rank: | Key | Geographic Area: | Large River / Lake | Life Stage: | Migratory adult & sub-adult |
|---|---|---|---|---|---|

Redband trout in the mainstem reaches of the Silvies River are highly vulnerable to predation by non-native fish species. Largemouth bass are present in the lower reaches of the Silvies River and smallmouth bass are common up to Seneca. Both of these species are predators of redband trout and pose the greatest threat to small juvenile and sub-adult trout as they out-migrate to the larger mainstem river habitats to rear. At high densities the largemouth and smallmouth bass populations can minimize recruitment of redband trout to the larger and older age-classes. In addition brook trout are present in the tributary streams of Bear, East Scotty and Myrtle creeks (ODFW NFIP unpublished data, WNTI 2012). Juvenile and resident adult redband trout in these reaches are vulnerable to predation by larger brook trout. Given the distribution of brook trout is limited to these few streams the threat is not considered to be as significant as that of non-native warm water species.

Competition

*Introduced Species*

(4a) – Reduced availability of prey and habitat resources

| Rank: | Key | Geographic Area: | Large River / Lake | Life Stage: | Migratory adult & sub-adult |
|---|---|---|---|---|---|

The mainstem Silvies River is occupied by a large warm water fish community. Non-native species that occupy the mainstem river include largemouth and smallmouth bass, common carp, brown bullhead, bluegill, pumpkinseed, crappie, and yellow perch. Redband trout compete with these species for limited habitat and prey resources particularly in reaches where habitat quality and complexity are limited. In the tributary streams of Bear, East Scotty and Myrtle creeks redband trout directly compete with brook trout, an ecological analog. While the species are able to co-exist there is evidence that redband trout sympatric with brook trout are present in lower densities and at smaller sizes than allopatric redband trout (Miller et al. 2014).

Physical Habitat

Aquatic habitat conditions in the Silvies River basin are generally degraded (HCWC 2001). The WNTI Range-wide Status Assessment (2012) rated habitat quality in all stream reaches, where 53% of the habitat was rated as in fair or poor condition, 31% was rated as in good or excellent condition and 16% unrated (WNTI 2012). Common factors include excessive sediment, low flows, lack of pool habitat, increased stream temperatures and degraded riparian areas. Similar to Silver Creek, almost all land management activities in the past century have negatively affected watershed processes. Grazing, agricultural practices, and timber harvest have impacted riparian zones eliminating shade, increasing erosion, removing large wood and reducing in-stream complexity. Bear Valley, the Upper Silvies Valley and Harney Valley historically were rich in wetland habitats (ODFW 2006). Trapping of beaver and draining of wetlands has not only reduced the system's ability to store and slowly release water, but has also eliminated complex off channel habitats optimal for rearing native trout.

*Water Management*

(6b) Stream Channelization

| Rank: | Key | Geographic Area: | Large River / Lake | Life Stage: | Migratory adult & sub-adult |
|---|---|---|---|---|---|

The mainstem river downstream from Fivemile Dam and Burns has been straightened and channelized in order to convey water more efficiently over the landscape and to drain wetlands for agricultural purposes. Bear Valley and Silvies Valley also have stream segments that are artificially straightened. Channel straightening eliminates the river's natural sinuosity, multiple channels, and off channel areas upon which migratory redband trout depend for holding, rearing, and feeding habitats.

(6c) Water Withdrawal

| Rank: | Key | Geographic Area: | Large River / Lake | Life Stage: | Migratory adult & sub-adult |
|---|---|---|---|---|---|

The withdrawal of water at diversions on the Silvies River and tributaries reduces the volume of available habitat for rearing and migration, significantly reducing the potential density and biomass of migratory redband trout. Water diversions occur throughout the watershed and are predominantly located above Seneca, in the Silvies River Valley, and downstream of Fivemile Dam on the East Fork of the Silvies River.

*Land Management*

(6d) Grazing, Timber and Riparian Management Practices

| Rank: | Key | Geographic Area: | Headwater / Tributary | Life Stage: | Eggs, juveniles & spawners |
|---|---|---|---|---|---|

Current and historical livestock grazing, agriculture, and timber harvest activities and their long term impacts have contributed to increased sediment input. The WNTI Range-wide Redband Trout Assessment (2012) identifies excessive sedimentation as an issue throughout the mainstem Silvies River and major tributary basins such as Bear, Trout, Myrtle, Camp, Crooked, Scotty and Emigrant creeks. Fine sediment that fills the interstitial spaces potentially suffocates eggs, degrades spawning habitat, embeds substrates and eliminates cover for fry. Sedimentation most dramatically impacts redband trout during spawning, egg incubation and rearing of fry and small juveniles.

(6e) Forest Roads

| Rank: | Secondary | Geographic Area: | Headwater / Tributary | Life Stage: | Eggs, juveniles & spawners |
|---|---|---|---|---|---|

High density forest roads are present in headwater tributaries of the Silvies River on US Forest Service property. Improperly located or maintained forest roads increase run-off and sedimentation of in-stream substrates. Embedded gravels and substrates reduce habitat complexity particularly for spawning adults, incubating eggs and all stages of fry & fingerlings. The headwater basins of Emigrant Creek (Whiskey, Sawtooth, Whiskey, Hay and Yellowjacket) and Camp Creek, and Upper Silvies River (above Seneca) are of particular concern (USFS 2010). The Malheur National Forest has implemented a travel management plan in this area that includes closing roads and restricting travel in areas recently affected by fire.

(6f) Grazing, Timber and Riparian Management Practices

| Rank: | Key | Geographic Area: | Large River / Tributary | Life Stage: | All |
|---|---|---|---|---|---|

Current and historical grazing and timber activity in the upper portion of the Silvies River basin has resulted in a loss of habitat complexity and degraded in-stream conditions. Removal of riparian vegetation and the subsequent stream bank erosion has caused incision of the stream channel and disconnected it from the floodplain. As a result redband trout have lost access to braided channels and off channel habitat. The resulting down cutting and bank destabilization has simplified the habitat and reduced complexity and riparian shading. The technical committee identified the lack of significant pool habitat (both in frequency and complexity) and lack of large wood in many of the tributaries as factors significantly impacting physical habitat quality. The WNTI Range-wide Redband Trout Assessment (2012) also noted a lack of pools or resting habitat in the mainstem reaches and many of the tributaries of Emigrant Creek, Myrtle Creek, Scotty, Creek, Bear Creek and headwaters above Seneca.

<u>Habitat Access</u>

*Water Management*

(7a) Dams and Diversions

| Rank: | Key | Geographic Area: | Large River / Lake | Life Stage: | Migratory adult & sub-adult |
|---|---|---|---|---|---|

Habitat access is impeded by impassable barriers on the mainstem Silvies River. The Fivemile Dam is not passable as well as multiple diversions on tributaries in Silvies Valley (Jump Creek, Bridge Creek, and Cottonwood Creek) and Emigrant Creek (Blue Creek and multiple other diversions). In addition numerous dams downstream of Burns prevent fish from migrating freely through the east and west forks. Inventory and status of these dams and diversions are not well documented. Many of these water diversions prevent passage upstream by migratory adults. Entrainment of juvenile fish moving downstream during high spring flows is also a problem at dams where diversions are unscreened. Additionally, historical channels that operated as natural sloughs and provided additional rearing habitat are now ephemeral ditches.

*Land Management*

(7b) – Forest Roads Culvert Crossings

| Rank: | Secondary | Geographic Area: | Headwater / Tributary | Life Stage: | Migratory adult & sub-adult |
|---|---|---|---|---|---|

Improperly placed culverts used for forest road crossings create barriers to fish migrating upstream. Problem culverts are either placed far enough above the streambed that fish cannot jump the distance required to access the culvert opening or installed at a steep enough angle to create a velocity barrier. These culverts prevent access to upstream spawning and rearing habitat. ODFW's fish barrier dataset identifies a culvert on Foundation Creek as impassable (ODFW 2012). Passage status at numerous other culverts within the basin is recorded as unknown (ODFW 2012). Forest roads and associated culverts in the headwater basins of Emigrant Creek (Whiskey, Sawtooth, Whiskey, Hay and Yellowjacket) and Camp Creek, and Upper Silvies River (above Seneca) are of particular concern (USFS 2010).

### A3.3 Factors and threats limiting viability of Poison Creek redband trout

**Table A3-4--Key and secondary limiting factors of the Poison Creek redband trout population. Bolded and shaded codes are key concerns and non-bolded/shaded codes are secondary concerns.**

| Threat | Headwaters / Tributaries | | | | |
|---|---|---|---|---|---|
| | egg | juvenile | resident sub-adult | resident adult | spawner |
| Water Management | | | | | |
| Land Management | 2g, 6d, **6e**, **6f**, 8b | | | | |
| Introduced Species | | | | | |
| Hatchery | | | | | |
| Harvest | | | | | |

The most significant limiting factor to Poison Creek redband trout is habitat condition, which varies from good to poor throughout the basin. Water quantity is naturally low; however, stream temperatures are very cold.

Water Quality

*Land Management*

(2g) – Non-point Source Pollution

| Rank: | Secondary | Geographic Area: | Headwater / Tributary | Life Stage: | All |
|---|---|---|---|---|---|

State Highway 395 follows the creek through Devine Canyon. Pollutants and toxins associated with road maintenance and vehicle use run off into the creek impacting water quality and redband trout physiology at all life stages.

Physical Habitat Quality

The WNTI Range-wide Redband Trout Assessment (2012) rated habitat in the Poison Creek basin as generally in good condition on public land, but conditions are unknown or appear poor based on visual observations. The 1990 Whiting Fire intensely burned much of Upper Poison Creek and Dry Creek. Stream channels on US Forest Service property within the fire boundary are currently shaded and stabilized (WNTI 2012). Physical in-stream habitat quality in the lower stream reaches is characterized by channel incision, sedimentation and simplification, all effects of current and historical land use activities.

*Land Management*

(6d) - Grazing, Timber and Riparian Management Practices

| Rank: | Secondary | Geographic Area: | Headwater / Tributary | Life Stage: | Eggs, juveniles & spawners |
|---|---|---|---|---|---|

Current and historical livestock grazing and agricultural activities and their long term impacts have contributed to increased sediment input particularly in the lower reaches of the creek. The WNTI Range-wide Redband Trout Assessment (2012) identifies excessive sedimentation as a factor in the lower reaches of Poison Creek. Fine sediment that fills the interstitial spaces potentially suffocates eggs, degrades spawning habitat, embeds substrates and eliminates cover for fry. Although sedimentation most dramatically impacts redband trout during spawning, egg incubation and rearing of fry and small juveniles, it is unknown if redband trout actively spawn in this particular reach.

(6e) Forest Roads

| Rank: | Key | Geographic Area: | Headwater / Tributary | Life Stage: | Eggs, juveniles & spawners |
|---|---|---|---|---|---|

High density forest roads are present in the Poison Creek drainage on US Forest Service property (USFS 2010). Improperly located or maintained forest roads increase run-off and sedimentation of in-stream substrates. Embedded gravels and substrates reduce habitat complexity particularly for spawning adults, incubating eggs and all stages of fry & fingerlings.

(6f) – Grazing, timber and riparian management practices

| Rank: | Key | Geographic Area: | Headwater / Tributary | Life Stage: | All |
|---|---|---|---|---|---|

Current and historical grazing and timber activity in the lower portion of Poison Creek basin has resulted in a loss of habitat complexity and degraded in-stream conditions. Down cutting of the stream channel has incised the channel and disconnected it from the floodplain. As a result redband trout have lost access to braided channels and off channel habitat. The resulting down cutting and bank destabilization has simplified the habitat, reduced complexity and minimized riparian shading. The technical committee identified the lack of suitable habitat and channel incision as factors significantly impacting physical habitat quality.

(6l) – Road Construction

| Rank: | Secondary | Geographic Area: | Headwater / Tributary | Life Stage: | All |
|---|---|---|---|---|---|

State highway 395 follows the stream channel through Devine Canyon. Channel constriction caused by highway construction hinders natural channel forming processes limiting habitat complexity, pool formation, and large wood recruitment.

<u>Other</u>

(8b) – Lack of access to private property

| Rank: | secondary | Geographic Area: | Headwater / Tributary | Life Stage: | All |
|---|---|---|---|---|---|

Fifteen kilometers (45%) of the redband trout distribution in Poison Creek is located on private property to which ODFW and other natural resource agencies have not been granted access. Habitat condition and population level factors are virtually unknown in these reaches preventing a thorough assessment of population status and limiting factors. The technical committee considered this lack of information a risk to understanding and adequately managing population viability of redband trout.

**A3.4 Factors and threats limiting viability of Prater Creek redband trout**

**Table A3-5.--Key and secondary limiting factors of the Prater Creek redband trout population. Bolded and shaded codes are key concerns and non-bolded/shaded codes are secondary concerns.**

| Threat | Headwater / Tributary | | | | |
|---|---|---|---|---|---|
| | egg | juvenile | resident sub-adult | resident adult | spawner |
| Water Management | | | | | |
| Land Management | **1e**, 8b | | | | |
| Introduced Species | | | | | |
| Hatchery | | | | | |
| Harvest | | | | | |

Data and ancillary information pertinent to limiting factors in Prater Creek is lacking. Based on professional judgment the technical committee believes water quantity is the most significant threat to redband trout in Prater Creek. Flows during low water years are intermittent and the upper reaches are dry during summer months. While many of the factors presumed to be contributing to low flow are not anthropogenic (small basin size, naturally porous soils, topology) current and historical land-use practices exacerbate the issue. In addition, access to private property in a significant portion of the distribution is prohibited, limiting our ability to assess population status and limiting factors.

<u>Water Quantity</u>

*Land Management*

(1e) - Grazing, Timber and Riparian Management Practices

| Rank: | Key | Geographic Area: | Headwater / Tributary | Life Stage: | All |
|---|---|---|---|---|---|

The technical committee cited porous soils, low snow pack (topology) and small basin size factors contributing to a low water volume. However, the long history of extensive land-use in the area exacerbates the condition. Heavy livestock grazing and extensive timber harvest since the late 1800's have impacted watershed processes and riparian areas (HCWC 2001). The removal of upland and riparian vegetation and soil compaction allowed precipitation to quickly run off instead of infiltrating the soil and recharging the water table. The lowered and depleted water table is unable to provide surface water during the summer and early fall or during drought years. Current land-use practices are thought to be substantially improved over those employed historically, but the legacy impacts remain.

<u>Other</u>

(8b) – No Agency Access

| Rank: | Secondary | Geographic Area: | Headwater / Tributary | Life Stage: | All |
|---|---|---|---|---|---|

Forty two percent of the estimated redband trout distribution in Prater Creek is located on private property to which ODFW and other natural resource agencies have not been granted access. Habitat condition and population level factors are virtually unknown in these reaches preventing a thorough assessment of population status and limiting factors. The technical committee considered this lack of information a risk to understanding and adequately managing population viability of Prater Creek redband trout.

**A3.5 Factors and threats limiting viability of Coffeepot Creek redband trout**

**Table A3-6.--Key and secondary limiting factors of the Coffeepot Creek redband trout population. Bolded and shaded codes are key concerns and non-bolded/shaded codes are secondary concerns.**

| Threat | Headwater / Tributary | | | | |
|---|---|---|---|---|---|
| | egg | juvenile | sub-adult | adult | spawner |
| Water Management | | | 7a | 7a | |
| | 1b, 2b, 2c | | | | |
| Land Management | 1e, **2e, 6f**, 8b | | | | |
| Introduced Species | | | | | |
| Hatchery | | | | | |
| Harvest | | | | | |

Limiting factors to redband trout viability in Coffeepot Creek are associated with water and habitat quality. Current and historical land-use practices have negatively impacted habitat structure and natural stream processes. In addition, the technical committee identified threats associated with water management that impact habitat in the lowest, possibly intermittent, reaches thereby limiting the potential for trout to occupy this portion of the watershed.

Water Quantity

*Water Management*

(1b) – Water withdrawal

| Rank: | Secondary | Geographic Area: | Headwater / Tributary | Life Stage: | All |
|---|---|---|---|---|---|

Water withdrawals and irrigation activities in the lower portion of the basin cause Coffeepot Creek to dry before it would naturally dissipate into the floor of Harney Valley (HCWC 2001). Drying of the lower reaches limits the volume of habitat available to redband trout. OWRD (unpublished data) has record of eleven points of diversion based on water rights certificates. On the ground verification and status of these diversions has yet to be confirmed.

*Land Management*

(1e) – Grazing, timber and riparian management practices

| Rank: | Secondary | Geographic Area: | Headwater / Tributary | Life Stage: | All |
|---|---|---|---|---|---|

Current and historical grazing and timber activities in the headwaters on US Forest Service and Bureau of Land Management (BLM) property have affected watershed condition and the hydrograph. Removal or degradation of upland and riparian vegetation reduce infiltration rates and increase the magnitude and frequency of high flows. The upper reaches flow through an open unconstrained canyon reach where the channel has become incised. The down cutting has disconnected the stream from the flood plain, drained hydric soils and lowered the water table reducing the magnitude of summer base flows.

Water Quality

Coffeepot Creek and its tributary, Mill Creek, are both included on ODEQ's 303d list of impaired waterways for exceeding stream temperature guidelines year around and during the summer, respectively (ODEQ 2010).

*Water management*

(2b) – Irrigation Practices

| Rank: | Secondary | Geographic Area: | Headwater / Tributary | Life Stage: | All |
|---|---|---|---|---|---|

Warm and turbid irrigation return flow and surface run-off are thought to decrease in-stream water quality. The technical committee identified this as a possible issue downstream of the narrow canyon where agricultural activities occur. Since the area of primary concern is downstream of what is thought to be redband trout distribution, irrigation practices are considered a secondary threat.

(2c) – Water withdrawal

| Rank: | Secondary | Geographic Area: | Headwater / Tributary | Life Stage: | All |
|---|---|---|---|---|---|

Water withdrawal at diversions lower in the basin contributes to elevated stream temperatures and decreased dissolved oxygen levels. Low water volume is highly susceptible to increases in water temperature during the summer months. Low flows are also susceptible to stagnation, further exacerbating low dissolved oxygen levels. These low flow and warm water conditions create inhospitable conditions for redband trout in the summer months. The technical committee identified water withdrawal as a threat to water quality in the downstream reaches of Coffeepot Creek. Since the area of primary concern is downstream of what is thought to be the downstream distribution of redband trout, water withdrawal is considered to be a secondary threat to water quality.

*Land Management*

(2e) – Grazing, Timber and Riparian Management

| Rank: | Key | Geographic Area: | Headwater / Tributary | Life Stage: | All |
|---|---|---|---|---|---|

The removal and degradation of riparian vegetation and associated streamside shading increases the exposure of the water's surface to solar radiation contributing to elevated in-stream water temperatures and a decrease in dissolved oxygen levels. Riparian condition is identified as a concern throughout the basin (USFS 2010). In addition the technical committee suggested grazing within and around headwater springs may cause a decrease of in-stream water quality.

<u>Physical Habitat</u>

Aquatic habitat conditions in Coffeepot Creek basin are generally rated as fair to good condition on public property (ODFW NFIP unpublished data, WNTI 2012, USFS 2010). Conditions on private property are undescribed.

*Land Management*

(6f) – Grazing, Timber and Riparian Management

| Rank: | Key | Geographic Area: | Headwater / Tributary | Life Stage: | All |
|---|---|---|---|---|---|

While some high quality habitat exists in Coffeepot Creek (WNTI 2012), the technical committee noted that upper stream reaches located in an open, unconstrained canyon on USFS and BLM property were entrenched and disconnected from the floodplain, likely a result of historical grazing and timber harvest activities. Reduced habitat heterogeneity and channel degradation was evident where exposed stream banks showed increased rates of erosion (USFS 2010).

<u>Habitat Access</u>

*Water Management*

(7a) – Dams and Diversions

| Rank: | Secondary | Geographic Area: | Headwater / Tributary | Life Stage: | Sub-adult & Adult |
|---|---|---|---|---|---|

Irrigation diversion structures and dams on the lower reaches of Coffeepot Creek may prevent redband trout from moving upstream. In addition diversions may entrain juvenile fish moving downstream into the irrigation system. The OWRD (unpublished data) has record of eleven points of diversion based on water rights certificates. On the ground documentation of passage and screening status of these diversions has yet to be confirmed.

Other

(8b) – Lack of access to private property

| Rank: | secondary | Geographic Area: | Headwater / Tributary | Life Stage: | All |
|---|---|---|---|---|---|

Seven kilometers (77%) of the redband trout distribution in Coffeepot Creek is located on private property to which ODFW and other natural resource agencies have not been granted access. Habitat condition and population level factors are virtually unknown in these reaches preventing a thorough assessment of population status and limiting factors. Given the large proportion of habitat on private property, the technical committee considered this lack of information a risk to understanding and adequately managing redband trout population viability.

**A3.6 Factors and threats limiting viability of Rattlesnake Creek redband trout**

**Table A3-7.--Key and secondary limiting factors of the Rattlesnake Creek redband trout population. Bolded and shaded codes are key concerns and non-bolded/shaded codes are secondary concerns.**

| Threat | Headwater / Tributary | | | | |
|---|---|---|---|---|---|
| | egg | juvenile | sub-adult | adult | spawner |
| Water Management | | | 7a | 7a | |
| | 1b, 2c | | | | |
| Land Management | 6d, 6e | | | | 6d, 6e |
| | 1e, 2e, **6f**, 6l | | | | |
| Introduced Species | | | | | |
| Hatchery | | | | | |
| Harvest | | | | | |

Threats to Rattlesnake Creek redband trout are primarily associated with decades of intensive land management (HCWC 2001). Historical grazing and timber harvest practices have caused basin-wide degradation of watershed processes culminating in sub-optimal conditions for trout. While current practices are vastly improved over those implemented in the past, current land and water use practices are either not adequate to restore habitat or hinder recovery in the headwater and low elevation reaches.

Water Quantity

Upper Rattlesnake Creek is ranked as 'in highest need' of stream flow restoration during the summer and 'in high need' during the spring and fall (OWRD and ODFW 2002). Basins with the highest rankings reflect the extent to which fish are negatively affected by reductions in-stream flows. Although only the upper basin is ranked high, the effects of low flow are often perpetuated, if not exacerbated, in the downstream reaches, particularly in small desert systems lacking springs and significant groundwater resources.

*Water Management*

(1b) - Water Withdrawal

| Rank: | Secondary | Geographic Area: | Headwater / Tributary | Life Stage: | All |
|---|---|---|---|---|---|

The operation of irrigation diversion dams interrupts the natural hydrograph, diverting and releasing water at times not historically typical. Water withdrawal decreases overall water volume and available in-stream habitat. Three diversions exist in the lower reaches of Rattlesnake Creek (based on Technical Team input, OWRD unpublished data) primarily impacting fish that use this reach for rearing and possibly spawning.

*Land Management*

(1e) – Grazing, Timber and Riparian Management Practices

| Rank: | Secondary | Geographic Area: | Headwater / Tributary | Life Stage: | All |
|---|---|---|---|---|---|

Historical grazing and timber harvest activities have impacted watershed processes, ultimately altering the character of the hydrograph. Removal and degradation of upland and riparian vegetation, along with soil compaction, decrease infiltration rates and increase overland flow during precipitation events. Over the long term, the watershed loses capacity to capture and retain water during the winter and spring and to slowly release water during dry periods. As a result flows can be high and flashy during precipitation and run0ff events and the stream may dry in the late summer and fall.

Water Quality

Water quality in Rattlesnake Creek is significantly degraded primarily due to high water temperatures (WNTI 2012, USFS 2010). The creek is listed on ODEQ's 303(d) list of impaired waterways for high temperatures year around (ODEQ 2010).

*Water Management*

(2c) - Water Withdrawal

| Rank: | Secondary | Geographic Area: | Headwater / Tributary | Life Stage: | All |
|---|---|---|---|---|---|

Water withdrawal at diversions in the lower basin contributes to elevated stream temperatures and decreased dissolved oxygen levels. Low water volume is highly susceptible to increases in water temperature during the summer months. Low flows are also susceptible to stagnation, further exacerbating low dissolved oxygen levels. When extreme, in magnitude or duration, these low flow and warm water conditions are inhospitable to trout.

*Land Management*

(2e) - Grazing, Timber and Riparian Management Practices

| Rank: | Secondary | Geographic Area: | Headwater / Tributary | Life Stage: | All |
|---|---|---|---|---|---|

The removal and degradation of riparian vegetation and streamside shading increase the exposure of the water's surface to solar radiation contributing to elevated in-stream water temperatures and decreased levels of dissolved oxygen. Although warm stream temperatures are a concern throughout the system, the lack of riparian shade is of particular concern in the lowest reaches of fish distribution (WNTI 2012).

Physical Habitat Quality

Habitat condition in the Rattlesnake Creek basin is generally characterized by sediment laden substrates, lack of complexity and habitat heterogeneity, and channel incision (WNTI 2012, USFS 2010). The WNTI Range-wide Redband Trout Status Assessment (2012) rated habitat quality in all stream reaches occupied by redband trout, where the 4.8 km on BLM property were rated as in good condition and the remaining 7.7 Km were in fair or poor condition (WNTI 2012).

*Land Management*

(6d) – Grazing, Timber and Riparian Management practices

| Rank: | Secondary | Geographic Area: | Headwater / Tributary | Life Stage: | All |
|---|---|---|---|---|---|

Historical and current grazing and timber management activities have resulted in excessive in-stream sediment input. The removal of riparian and upland vegetation has increase overland flow and erosion during precipitation events increasing the overall sediment load of the stream. Fine sediments fill interstitial spaces decreasing the quality of spawning gravels and the available cover for young-of-the-year trout. Excessive sediment was identified as impacting habitat quality throughout the basin (WNTI 2012).

(6e) – Forest Roads

| Rank: | Secondary | Geographic Area: | Headwater / Tributary | Life Stage: | Eggs, juveniles & spawners |
|---|---|---|---|---|---|

The construction and maintenance of forest roads serves as a source of in-stream sediment. The Rattlesnake Creek basin is moderately roaded (USFS 2010) and a road follows the stream corridor along most of Rattlesnake Creek. Runoff from the road contributes to the increased in-stream sediment volume.

(6f) – Grazing, Timber and Riparian Management Practices

| Rank: | Key | Geographic Area: | Headwater / Tributary | Life Stage: | All |
|---|---|---|---|---|---|

Historical and current land-use practices have significantly impacted the physical in-stream habitat in Rattlesnake Creek. The degradation and removal of upland and riparian vegetation over decades of grazing and timber harvest has led to the incision of the stream channel. This down-cutting has created unstable banks, a loss of habitat complexity and heterogeneity, and the disconnection from the floodplain and any off-channel habitats that may have been present historically. Although current land use practices have greatly improved over those implemented historically, present day activities prevent the stream from recovering at an appreciable rate in the headwater reaches (USFS property) and at the lowest elevations (based on Technical Team input). However, the re-establishment of the riparian plant community in the middle reaches (BLM property) has started to stabilize the stream banks and create mid-day shade (based on Technical Team input, WNTI 2012).

(6l) - Forest Roads

| Rank: | Secondary | Geographic Area: | Headwater / Tributary | Life Stage: | All |
|---|---|---|---|---|---|

The stream channel is constrained by a rural road that impairs natural channel forming processes, limiting habitat complexity, pool formation and large wood recruitment. Channel constriction is a particular problem on BLM property (based on Technical Team input)

Habitat Access

*Water Management*

(7a) – Water Withdrawal - Dams & Diversions

| Rank: | Secondary | Geographic Area: | Headwater / Tributary | Life Stage: | Adult & sub-adult |
|---|---|---|---|---|---|

The irrigation diversion structures in the lowest reach of Rattlesnake Creek may prevent redband trout from moving upstream. These same dams may also entrain fish into the irrigation system as they move downstream. While the presence of three dams on the lower portion of Rattlesnake Creek has been verified, the details of passage and screening status are unknown (based on Technical Team input, OWRD unpublished data).

**A3.7 Factors and threats limiting viability of Cow Creek redband trout**

**Table A3-8.--Key and secondary limiting factors of the Cow Creek redband trout population. Bolded and shaded codes are key concerns and non-bolded/shaded codes are secondary concerns.**

| Threat | Headwater / Tributary | | | | |
|---|---|---|---|---|---|
| | egg | juvenile | sub-adult | adult | spawner |
| Water Management | | | 7a | | |
| | **1b** | | | | |
| Land Management | 6d, 6e | | | | 6d, 6e |
| | **1e, 2e, 6f** | | | | |
| Introduced Species | | | | | |
| Hatchery | | | | | |
| Harvest | | | | | |

Factors affecting the viability of Cow Creek redband trout are primarily related to water quantity and physical habitat quality. Stream flow is intermittent during low water years where the upper and middle reaches are periodically dry (ODFW, NFI unpublished data). Excessive sedimentation, trampled stream banks, and deteriorated riparian areas have degraded physical habitat quality throughout the basin.

Water Quantity

Water quantity appears to be the most significant limiting factor in Cow Creek. Most of Cow Creek is characterized by inadequate or intermittent stream flow (WNTI 2012). Surveys conducted to sample redband trout 2007 – 2011 found multiple dry sites throughout the watershed (Miller 2010, and ODFW NFI unpublished data). While natural factors exist that contribute to low flow (small basin size, naturally porous soils, and topology) current and historical water and land-use practices exacerbate the condition.

*Water Management*

(1b) - Water Withdrawal

| Rank: | Key | Geographic Area: | Headwater / Tributary | Life Stage: | All |
|---|---|---|---|---|---|

Withdrawal of water at diversions disrupts the natural hydrograph, diverting and releasing water at times not historically typical. Water withdrawal also decreases overall water volume and available in-stream habitat. One diversion occurs high in the watershed, potentially impacts all downstream reaches and all life stages. Based on water rights certificates OWRD (unpublished data) has record of 8 other points of diversion in Cow Creek, all downstream of suspected fish distribution. Other diversions exist in tributaries and as well as wells within the basin. On the ground verification and operational protocol of these diversions has yet to be determined (Tech Team 2012).

*Land management*

(1e) – Grazing, timber and riparian management practices

| Rank: | Key | Geographic Area: | Headwater / Tributary | Life Stage: | All |
|---|---|---|---|---|---|

Historical and current grazing and timber management activities have negatively impacted the riparian and upland areas of Cow Creek. Extensive timber harvest and livestock grazing have largely affected rangeland and riparian vegetation since the late 1800's having substantial long term effects on watershed processes (HCWC 2001). Current land-use practices are substantially improved over those employed historically, but many of the impacts remain. The combined consequence of livestock grazing and timber harvest has dramatically affected watershed processes and riparian condition where precipitation quickly runs off instead of infiltrating and recharging the water table for slow release during summer months. The results include extremely low flows or drying in the summer and early fall or during drought years.

<u>Water Quality</u>

Cow Creek is not listed on the ODEQ 303(d) list of impaired waterways, not because water quality criteria were met for temperature, dissolved oxygen and sediment, but because data were insufficient to accurately evaluate these conditions. At a minimum, the technical team believes water temperature is excessively high during hot periods and summer months.

*Land Management*

(2e) – Grazing, Timber and Riparian Management Practices

| Rank: | Key | Geographic Area: | Headwater / Tributary | Life Stage: | All |
|---|---|---|---|---|---|

The removal and degradation of riparian vegetation and associated streamside shading increases the exposure of the water's surface to solar radiation. Increased radiation rates elevate in-stream water temperatures, particularly during the summer when solar exposure is longer duration. Stream reaches not shaded by the forest canopy are the most vulnerable.

<u>Physical Habitat Quality</u>

*Land Management*

(6d) - Grazing, Timber and Riparian Management Practices

| Rank: | Secondary | Geographic Area: | Headwater / Tributary | Life Stage: | eggs, juveniles, spawners |
|---|---|---|---|---|---|

Current and historical timber harvest activities and livestock grazing have contributed to increased sediment input in Cow Creek. Fine sediment fills interstitial spaces potentially suffocating eggs, degrading spawning habitat and embedding substrates which eliminates cover for fry and young of the year. The technical committee noted that excessive sediment input is a habitat quality issue in stream reaches on public land. Conditions on private property are unknown but suspected to be similar to that on federally owned property.

(6e) Forest Roads

| Rank: | Secondary | Geographic Area: | Headwater / Tributary | Life Stage: | eggs, juveniles, spawners |
|---|---|---|---|---|---|

While forest roads are not overly extensive in the Cow Creek basin, they exist in a basin already impacted by land use. Improperly located or maintained forest roads increase run-off and sedimentation of in-stream substrates. Embedded gravels and substrates reduce habitat complexity particularly for spawning adults, incubating eggs and all stages of fry & fingerlings. Forest roads are most concentrated on USFS property in the headwater reaches and a road follows the stream corridor in the upper and lower most reaches.

(6f) Grazing, Timber, and Riparian Management Practices

| Rank: | Key | Geographic Area: | Headwater / Tributary | Life Stage: | All |
|---|---|---|---|---|---|

Long term grazing and timber harvest activities in Cow Creek basin has resulted in reduced habitat heterogeneity and significant channel degradation. The removal of riparian vegetation and the trampling of streamside banks has reduced bank stability and simplified the habitat.

Habitat Access

*Water Management*

(7a) Dams and Diversions

| Rank: | Secondary | Geographic Area: | Headwater / Tributary | Life Stage: | sub-adult & adult |
|---|---|---|---|---|---|

The OWRD (unpublished data) has record of eight points of diversion in the lowest reaches of Cow Creek, at or below suspected fish distribution. On the ground documentation of the passage and screening status of these diversions has not occurred. The technical committee noted that in the absence of these dams and diversions redband trout distribution may extend further downstream. In addition, if fish are able to move downstream of the diversions and survive they may not be able return to upstream reaches.

**A3.8 Factors and threats limiting viability of Riddle Creek redband trout**

**Table A3-9.--Key and secondary limiting factors of the Riddle Creek redband trout population. Bolded and shaded codes are key concerns and non-bolded/shaded codes are secondary concerns.**

| Threat | Headwater / Tributary | | | | | Large River / Lake | |
|---|---|---|---|---|---|---|---|
| | egg | juvenile | resident sub-adult | resident adult | spawner | migratory sub-adult | migratory adult |
| Water Management | | | | | | **1b, 2c,** 6b, 6c, **7a** | |
| Land Management | **2e, 6f,** 6h, 8b | | | | | **2e** | |
| Introduced Species | | | | | | | |
| Hatchery | | | | | | | |
| Harvest | | | | | | | |

Threats limiting redband trout in the Riddle Creek sub-basin primarily occur in the low elevation reaches, downstream of Smyth Reservoir. Conditions here likely prevent redband trout from rearing in these reaches, limiting the expression of the migratory life history. Habitat quality in Smyth Creek below the reservoir and Riddle Creek between Paul Creek and Dry Lake Reservoir is severely degraded (WNTI 2012). Irrigation operations in these reaches divert flow from the natural channel into a series of human-made canals and artificial channels, leaving the natural stream course dry (Tech Team 2012). Impassable barriers at Smyth Reservoir and Dry Lake Reservoir prevent fish rearing in these habitats from returning upstream to spawn, ultimately decreasing productivity and life history diversity.

In addition, habitat conditions in the headwater streams potentially impact redband trout. In-stream habitat in Upper Smyth, Riddle and Coyote creeks was rated as in fair condition (WNTI 2012), and Coyote and Paul creeks experience high stream temperatures year around and during the summer months, respectively (ODEQ 2010).

Water Quantity

*Water Management*

(1b) - Water Withdrawal

| Rank: | Key | Geographic Area: | Large River / Lake | Life Stage: | Sub-adult, Adult |
|---|---|---|---|---|---|

Low water volume was identified as a limiting factor for redband trout in lower Smyth Creek downstream of Smyth Reservoir (WNTI 2012) and in lower Riddle Creek downstream of the confluence with Paul Creek (based on Technical Team input). In these reaches water is diverted from the main channel into irrigation canals. The decrease or elimination of flow in the natural channel reduces the volume and quality of available habitat, and significantly alters of the timing and magnitude of the hydrograph. Surface water is at or near full appropriation during the summer months (HCWC 2001).

Water Quality

Coyote Creek and Paul Creek included on ODEQ's 303d list of impaired waterways for high year around and summer temperatures, respectively (ODEQ 2012). High summer water temperature and the associated decrease in dissolved oxygen were identified as factors affecting redband trout habitat in the low elevation reaches of Riddle and Smyth Creeks (WNTI 2012).

*Water Management*

(2c) - Water Withdrawal

| Rank: | Key | Geographic Area: | Large River / Lake | Life Stage: | Sub-adult, Adult |
|---|---|---|---|---|---|

Water withdrawal at diversions on lower Riddle and Smyth creeks contributes to elevated stream temperatures and a decrease in dissolved oxygen. Lower water volume is highly susceptible to increases in water temperature during summer months. Low flows are also susceptible to stagnation; further exacerbating low levels of dissolved oxygen. In addition, irrigation return and agricultural run-off may increase in-stream water temperatures (based on Technical Team input). Low flow and warm water temperatures combine to create inhospitable conditions for rearing and migrating redband trout.

*Land Management*

(2e) - Grazing, Timber and Riparian Management Practices – Water Temperature

| Rank: | Key | Geographic Area: | All | Life Stage: | All |
|---|---|---|---|---|---|

Historical grazing practices have eliminated riparian vegetation or reduced riparian condition throughout the watershed (based on Technical Team input). Streamside shading is lacking in both the upper (Coyote, upper Smyth, and upper Riddle creeks) and lower portions of the watershed (lower Smyth and Riddle creeks) (WNTI 2012). The lack of riparian shading increases the exposure of the water's surface to solar radiation, contributing to elevated in-stream water temperatures and low levels of dissolved oxygen.

Physical Habitat Quality

Habitat quality in the lower portion of the watershed is severely degraded, impacted by water withdrawal and agricultural activities. Habitat in Lower Riddle Creek is characterized by high sediment volume, lack of shade, and high temperatures (WNTI 2012). The headwaters of Coyote, Riddle and Smyth creeks are reported to be high in sediment volume, and low in shade and pool habitat (WNTI 2012). Stream reaches in these headwater streams are rated as not in Proper Functioning Condition by the BLM (HCWC 2001). Historical grazing practices and juniper encroachment have degraded riparian areas and simplified in-stream habitats. Current practices have improved significantly over those implemented historically (based on Technical Team input) and land management actions are being implemented to improve or restore natural conditions.

*Water Management*

(6b) Channelization

| Rank: | Secondary | Geographic Area: | Large River / Lake | Life Stage: | Sub-adult, Adult |
|---|---|---|---|---|---|

To efficiently transport water over the landscape, portions of lower Riddle and Smyth creeks have been straightened and channelized or simply bypassed via irrigation ditches (Tech Team 2012). Absent of the stream's natural sinuosity, off channel habitats, secondary channels and riparian vegetation these reaches are lacking the structure necessary to provide adequate holding, rearing and feeding habitats for trout. The lowest reaches of Riddle Creek are characterized by excessive sedimentation (WNTI 2012).

(6c)- Water Withdrawal

| Rank: | Secondary | Geographic Area: | Large River / Lake | Life Stage: | Sub-adult, Adult |
|---|---|---|---|---|---|

The withdrawal of water at diversions on lower Riddle and Smyth creeks decreases the volume and quality of habitat trout typically utilize for rearing and migration. As a result the potential trout density and biomass are reduced impacting overall population level productivity. A reduction in suitable or even adequate rearing habitat minimizes the potential for redband trout to express a migratory life history. In addition, low water volume also hinders hydrologic channel forming processes that create pools, riffles and other habitat types.

*Land Management*

(6f) – Grazing, Timber and Riparian Management Practices - Degradation

| Rank: | Key | Geographic Area: | Headwater /Tributary | Life Stage: | All |
|---|---|---|---|---|---|

Historical and current grazing practices have impacted the quality of in-stream habitat throughout the Riddle Creek watershed. The removal or degradation of riparian vegetation has resulted in a general decrease in habitat quality. The loss of bank roughness and root strength exposes stream banks to greater erosive forces during medium to high flow events, resulting in channel widening, increased sedimentation, and shallower and simpler pool habitat often with little cover. The headwater reaches of Coyote, Riddle, and Smyth creeks are characterized by minimal streamside shading and low pool frequency (WNTI 2012). Upland grazing activity increases in-stream sedimentation. While historical grazing activities have had the greatest impact and current practices are still influential in areas, a more riparian friendly grazing regime has been implemented in the upper watershed (Tech Team 2012).

(6h) Juniper Encroachment

| Rank: | Secondary | Geographic Area: | Headwater /Tributary | Life Stage: | All |
|---|---|---|---|---|---|

Encroachment of western juniper alters the hillslope or watershed level hydrologic response to precipitation events. The decrease in cover of shrub and herbaceous vegetation associated with the dominance of juniper makes soil more susceptible to raindrop impact that increases soil crusting, lowers infiltration rates and increases over land erosion (Miller et al. 2005). As a result measureable soil erosion is generated by lower intensity, and therefore more frequent, precipitation events, and the volume of sediment produced and delivered to streams and creeks is greater relative to non-juniper dominated hillslopes (Miller et al. 2005). In addition, increased sediment delivery in juniper dominated systems is exacerbated by the replacement of the riparian community by juniper. The loss of native riparian vegetation results in unstable banks, channel incision, and increased exposure to solar radiation (Barrett 2007).The BLM has conducted numerous juniper removal projects on in the headwaters of Paul, Coyote, Smyth, and Riddle creeks with the intention of restoring riparian and upland plant communities and reducing fuel loads for fire (BLM, unpublished data).

<u>Habitat Access</u>

*Water Management*
(7a) Dams & Diversions

| Rank: | Key | Geographic Area: | Large River / Lake | Life Stage: | Sub-adult, Adult |
|---|---|---|---|---|---|

Movement of redband trout is impeded by dams and diversion structures in the lower watershed. Redband trout that move into Dry Lake Reservoir or downstream past Smyth Reservoir are unable to return to the upper watershed. A dam at Smyth Reservoir prevents fish residing downstream of the dam from moving upstream into the lake and upper Smyth Creek (WNTI 2012). Similarly, a dam at Dry Lake Reservoir prevents fish from moving up out of the reservoir into Riddle Creek. Thus if fish move into Dry Lake when the conditions allow, they are unable to return to Riddle Creek. During high water years fish may be able to move downstream of Dry Lake Reservoir, but are entrained there since passage upstream into the reservoir does not exist (Tech Team 2012).

<u>Other</u>
*<u>8b –No Agency Access</u>*

| Rank: | Secondary | Geographic Area: | Headwater / Tributary | Life Stage: | All |
|---|---|---|---|---|---|

Fish and habitat data are lacking for reaches in Paul Creek and mid-elevation reaches of Riddle Creek. Seventy-seven percent of redband trout distribution on Paul Creek and 53% on Riddle Creek are located on private property, to which ODFW and other natural resource agencies have not been granted access. Habitat condition and population level factors are virtually unknown in these reaches preventing a thorough assessment of population status and limiting factors. The technical committee considered this lack of information a risk to understanding and adequately managing population viability of redband trout.

**A3.9 Factors and threats limiting viability of Blitzen redband trout**

**Table A3-10**.--**Key and secondary limiting factors of the Blitzen River redband trout population. Bolded and shaded codes are key concerns and non-bolded/shaded codes are secondary concerns.**

| Threat | Headwater / Tributary | | | | | Large River / Lake | |
|---|---|---|---|---|---|---|---|
| | egg | juvenile | resident sub-adult | resident adult | spawner | migratory sub-adult | migratory adult |
| Water Management | | | | | | 1b, 1h, 2b, **2c**, **6b**, **6c**, **7a** | |
| Land Management | | | **6f,** 6h | | | **2e,** 2g**, 6f** | |
| Introduced Species | | | | | | 2j, 4a | |
| Hatchery | | | | | | | |
| Harvest | | | | | | | |

The Blitzen River (Blitzen) is considered to be one of the crown jewels of redband trout habitat in Oregon's high desert. The headwater streams in the Steens Mountain are thought to be close to pristine and capable of supporting a healthy population of redband trout. This is fairly accurate when compared to other high desert redband trout populations; however the Blitzen River Basin is not without conditions hampering abundance, productivity, spatial structure and diversity of the redband trout population.

Settled in the late 1800's, the Blitzen Valley quickly became the center for sheep and cattle grazing operations in the region. The following decades of heavy grazing and associated activities impacted most of the streams throughout the basin. Recent grazing restrictions have allowed many riparian habitats to recover. The Blitzen River above Fish Creek is now the nation's first redband trout reserve where land management activities promote environmental education, fish and wildlife recreation, and scientific research (BLM 2005).

Currently, threats to redband trout VSP parameters have the greatest impact in the lower elevation streams including the lower Blitzen River through the Malheur National Wildlife Refuge (MNWR) and the lower reaches of Kiger and McCoy drainages. Cattle grazing and irrigated hay production prompted the development of a system of dikes, canals, drains and water control structures in the lower Blitzen Valley in the late 1800s. The system was used to control the movement of water across the landscape and to drain wetlands for grazing and farming activities (Burnside 2008). Today, more than 900 water control structures exist in the Blitzen Valley as part of the intensive delivery system used by the Malheur National Wildlife Refuge to manage ponds, meadows, and wetlands for migratory birds and wildlife (USFWS 2012). These threats, channel straightening, dams and diversions and agricultural practices, also impact fish and their habitat in the lower portion of McCoy and Kiger Creeks.

Water Quantity

Although the hydrograph in the upper basin has generally maintained its historical character, the low elevation reaches of the Blitzen River and Kiger and McCoy Creeks is significantly altered. Water and land use practices have contributed to low flow conditions and altered the flow regime. The lower reaches of McCoy and Kiger Creeks are characterized by inadequate flow particularly during the warm summer months (WNTI 2012). The low elevation reaches of the Blitzen River and Cucamonga Creek are ranked highest priority for flow restoration and Kiger and McCoy Creeks are ranked as high priority (OWRD and ODFW 2002).

*Water Management*

(1b) – Water Withdrawal

| Rank: | Secondary | Geographic Area: | Large River / Lake | Life Stage: | Sub-adult, Adult |
|---|---|---|---|---|---|

The mean annual discharge of the Blitzen River at the USGS gauging station upstream of the refuge is 91,000 acre-feet, whereas the mean annual flow at the mouth in Malheur Lake is 60,000 acre-feet (USFWS 2012). Typically rivers accumulate flow in the downstream direction. The decrease in flow exhibited here is the direct result of the Refuge diverting water at 6 diversion dams, into 10 irrigation canals, along the lower reaches of the Blitzen River (USFWS 2012). Although the MNWR maintains a minimum flow of 25cfs in the Blitzen River with the intention of supporting migratory redband trout (USFWS 2012), this amount may not be adequate during certain times of the year.

Oregon Water Resources Department has record of 42 points of diversion on lower McCoy and Kiger creeks (OWRD unpublished data). These records are based on water rights certificates and absent of on the ground verification, however, collectively are indicative of the degree to which water has been over appropriated in this basin (HCWC 2003).

(1h) – Irrigation Operations

| Rank: | Secondary | Geographic Area: | Large River / Lake | Life Stage: | Sub-adult, Adult |
|---|---|---|---|---|---|

The Malheur Wildlife Refuge has more than 900 water control structures in the Blitzen Valley as part of an intensive water delivery system to manage ponds, wetlands, and meadows for wildlife (USFWS 2012). Water is taken from the mainstem Blitzen River during spring high flow events and used to flood irrigate meadows and wetlands before it returns to the mainstem through irrigation return, surface sheet flow, or subsurface percolation. On a gross level this flow-through delivery system is thought to mimic the natural flooding regime typical during spring peak flow events. However, on a smaller scale, MNWR operations manipulate the water level in standing water habitats to create conditions beneficial to nesting birds. The management of these habitats can require the Refuge to divert large volumes of water during low-flow periods or to suddenly drain a wetland or pond resulting in high and relatively dramatic changes to in-river flow (based on Technical Team input). These alterations in timing and magnitude of flows can negatively affect redband trout, their habitat, and the prey base upon which they rely.

<u>Water Quality</u>

The Blitzen River, McCoy, Krumbo, Bridge, Little Blitzen, and Indian Creeks and Bridge Creek Canal are included on the ODEQ 303(d) list of impaired waterways for year around water temperature and Mud, Ankle, Fish and Deep creeks are listed for summer temperatures. In addition Bridge Creek is listed for high levels of beryllium, iron, and manganese and Little Blitzen River is listed for beryllium (ODEQ 2010). A study of water quality on the MNWR conducted in 2002-2003 identified conductivity, dissolved oxygen, turbidity, suspended sediment, total phosphorus and total nitrogen as parameters of concern in the Blitzen River (Mayer et al 2007, USFWS 2012). All of these parameters increased in concentration in the downstream direction with the exception of dissolved oxygen, which decreased closer to the Lake.

*Water Management*

(2b) – Irrigation Practices

| Rank: | Secondary | Geographic Area: | Large River / Lake | Life Stage: | Sub-adult, Adult |
|---|---|---|---|---|---|

Water diverted for irrigation comes back to the main river through irrigation return, surface sheet flow, or subsurface percolation. In-stream water quality maybe degraded through the addition of this return flow due to increased water temperature (USFWS 2012). The return flow also contributes to low dissolved oxygen and higher biological oxygen demand. In addition turbidity levels increase when the dams are opened after irrigation season (USFWS 2012).

(2c) – Water Withdrawal

| Rank: | Key | Geographic Area: | Large River / Lake | Life Stage: | Sub-adult, Adult |
|---|---|---|---|---|---|

Water withdrawal at diversions within the basin contributes to elevated stream temperatures and decreased dissolved oxygen levels. Low water volume is highly prone to increases in water temperature during the summer months. Low flows are also susceptible to stagnation, further exacerbating low dissolved oxygen levels. These low flow and warm water conditions can create an inhospitable environment for redband trout.

*Land Management*
(2e) – Grazing, Timber & Riparian Management

| Rank: | Key | Geographic Area: | Large River / Lake | Life Stage: | Sub-adult, Adult |
|---|---|---|---|---|---|

The removal and degradation of riparian vegetation and associated streamside shading increases the exposure of the water's surface to solar radiation which contributes to elevated in-stream water temperatures and a decrease in dissolved oxygen. Historical grazing practices and the purposeful eradication of riparian habitats throughout the Blitzen River basin has reduced the quality and quantity of riparian shading (USFWS 2012). Current grazing practices on the Refuge and on Steens Mountain are much improved though riparian conditions in some areas are slow to recover. Riparian condition is identified as an issue of concern in lower Bridge Creek, Blitzen between Bridge Creek Canal and Krumbo Creek, lower Krumbo Creek, the Diamond Drain, lower Kiger Creek and Cucamonga Creek (WNTI 2012).

(2g) – Non-Point Source Pollution

| Rank: | Secondary | Geographic Area: | Large River / Lake | Life Stage: | Sub-adult, Adult |
|---|---|---|---|---|---|

Because the rural landscape is dominated by ranching and agricultural activities there is potential for contamination from fertilizers and other agrochemicals topically applied to flood irrigated meadows (USFWS 2012). In the MNWR, water quality testing specific to pesticides has not occurred since the late 1980's when they were detected in the lake but thought not to be causing significant harmful effects to human or resource health (Rinella & Schuler 1992, USFWS 2012). Irrigation drainage is considered to also contribute to increased turbidity, macronutrient concentration and conductivity in the lower Blitzen River and in Diamond Valley.

*Introduced Species*
(2j) – Common Carp

| Rank: | Secondary | Geographic Area: | Large River / Lake | Life Stage: | Sub-adult, Adult |
|---|---|---|---|---|---|

The USFWS considers Common Carp to be the single most significant threat to aquatic health on the MNWR (USFWS 2012). Carp were introduced to the basin in the 1930s and are now currently abundant in Malheur Lake and the Lower Blitzen River. Carp control in Malheur Lakes, Blitzen Valley, Silvies River, and on the Double O Ranch is a priority for the MNWR (USFWS 2012). Carp search for benthic macroinvertebrate prey by rooting around in the substrates; this behavior suspends sediment in the water column significantly increasing turbidity. Redband trout are visual predators requiring somewhat clear water to successfully locate and capture prey. Most water bodies invaded by carp have transitioned from a macrophyte-dominated, clear-water stable state to a phytoplankton-dominated, turbid water state (USFWS 2012). The increase in phytoplankton results in an increase in algal blooms which causes a decrease in dissolved oxygen levels. The decline in water quality as a result of carp feeding behavior and high densities are a direct threat to migratory redband trout that occupy Malheur Lake and the Lower Blitzen River for rearing and migration.

<u>Competition</u>
*Introduced Species*
(4a) – Common Carp

| Rank: | Secondary | Geographic Area: | Large River / Lake | Life Stage: | Sub-adult, Adult |
|---|---|---|---|---|---|

In addition to altering the condition of physical habitat, Common Carp in the lower Blitzen River and Malheur Lake also compete directly for space and indirectly for macroinvertebrate prey, reducing potential growth for adult rearing fish. Carp likely have a competitive advantage over redband trout given they are better adapted to the warm water temperatures and degraded environmental conditions in these habitats.

Physical Habitat Quality

Physical in-stream habitat condition in the upper Blitzen River is considered to be some of the highest quality in the Oregon portion of the Great Basin (WNTI 2012). Habitat quality in the upper Blitzen River and tributary streams upstream of the refuge was rated as in excellent or good condition. However habitat quality in lower elevation streams is compromised by historical grazing and current irrigation activities. The Blitzen River below the confluence of Bridge Creek is deeply incised and does not support floodplain hydrology or riparian vegetation (USFWS 2012), and habitat is fairly homogeneous dominated by flatwater glides and lacking in frequent and distinct pools and riffles (Salant et al. 2011, WNTI 2012). In-stream habitat in the lower McCoy and Kiger Creeks is degraded and rated as poor quality, characterized by excessive sediment, degraded riparian zones, unstable banks and a lack of habitat complexity (WNTI 2012).

(6b) – Steam Channelization

| Rank: | Key | Geographic Area: | Large River / Lake | Life Stage: | Sub-adult, Adult |
|---|---|---|---|---|---|

In the early 1900s eighteen miles of the lower Blitzen River were channelized and straightened as part of a complex system of canals, dikes, and drains developed to facilitate farming and grazing the wetlands of Blitzen Valley. The Blitzen River was also diked and deepened in many places and more than 50 miles of secondary channels were excluded from riverine hydrology. Channelization destroyed habitat complexity on large reaches of river and is believed to have reduced the abundance of native fish species (USFWS 2012). As a result current habitat conditions in the lower river are degraded and structure is overly simplified. Very little habitat heterogeneity exists in mainstem Blitzen River where flat water dominates and deep pools and riffles are less common (Salant et al. 2012). Krumbo Creek below the reservoir, the lower Blitzen River up to the East Canal, the East Canal and lower Bridge Creek were identified as containing either <35% or > 60% pool habitat (WNTI 2012, Salant et al. 2012), whereas lower Kiger, Cucamonga, Krumbo, Bridge creeks and the Blitzen River between Krumbo and Fish Creek were characterized as high in fine sediment (WNTI 2012). Diamond Drain and the lower portions of Kiger and Cucamonga creeks are also straightened and channelized and also suffer from oversimplified aquatic habitat (USFWS 2012).

(6c) – Water Withdrawal

| Rank: | Key | Geographic Area: | Large River / Lake | Life Stage: | Sub-adult, Adult |
|---|---|---|---|---|---|

Withdrawal of water at diversions on the Blitzen River and in the Kiger and McCoy basins reduces the volume and quality of habitat available for rearing and migration. The Diamond Drain and the lower reaches of Kiger, Booner's and McCoy creeks were characterized as having inadequate flow (WNTI 2012). The lower volume of habitat reduces the potential density and biomass of migratory redband trout. Low water volume also hinders hydrologic channel forming processes that create pools, riffles and other habitat types.

*Land Management*

(6f) – Grazing, Timber, and Riparian Management

| Rank: | Key | Geographic Area: | All | Life Stage: | All |
|---|---|---|---|---|---|

Heavy sheep and cattle grazing on the Steens Mountain and in Blitzen Valley since the 1880's have resulted in the degradation of riparian areas and the upland range. Impacts of riparian degradation to in-stream habitats include excessive silt loading, channel incision, loss of habitat complexity, and a decrease or absence of shade. Restrictions on livestock grazing on the Refuge were implemented in the 1970s, and much of the upper Blitzen River watershed upstream of Fish Creek is currently cattle free (based on Technical Team input, BLM unpublished data). As a result, riparian habitat associated with riverine systems has recovered in the South Blitzen Valley and in the headwaters. Riparian condition remains poor where stream channels are incised or water is diverted particularly in the low elevation reaches of McCoy Creek, Kiger Creek, Diamond Drain and portions of the Refuge (USFWS 2012, WNTI2012)

(6h) – Juniper Encroachment

| Rank: | Secondary | Geographic Area: | Headwater / Tributary | Life Stage: | All |
|---|---|---|---|---|---|

Dominance of western juniper alters the hillslope or watershed level hydrologic response to precipitation events. The decrease in cover of shrub and herbaceous vegetation associated with the encroachment of juniper makes soil more susceptible to raindrop impact that increases soil crusting, lowers infiltration rates and increases over land erosion (Miller et al. 2005). As a result measureable soil erosion is generated by lower intensity, and therefore more frequent, precipitation events. The volume of sediment produced and delivered to streams and creeks is greater relative to non-juniper dominated hillslopes (Miller et al 2005). In addition, increased sediment delivery in juniper dominated systems is exacerbated by the replacement of the riparian community by juniper. The loss of native riparian vegetation results in unstable banks, channel incision, and increased exposure to solar radiation (Barrett 2007). The BLM has conducted numerous juniper removal projects on Steens Mountain in the headwaters of Kiger and McCoy Creeks with the intention of restoring riparian and upland plant communities and watershed processes (BLM, unpublished data).

Habitat Access – Passage and Entrainment

The Blitzen River contains one of the more abundant migratory redband trout populations in the Great Basin. In the fall, fish move to the lower river and, when conditions allow, Malheur Lake to overwinter. In the spring and summer trout migrate to the upstream reaches to spawn and to avoid inhospitable conditions created by high water temperatures (Anderson 2009). Because these habitats are spatially segregated, successful completion of their life-cycle is dependent on connectivity throughout the river system. The water management structures in the lower rivers and creeks dramatically impacts the duration and success of migration. For spawning trout, the duration and timing of the upstream migration is critical to the completion of the life cycle and overall fitness.

*Water Management*

(7a) – Diversions and Irrigation Dams

| Rank: | Key | Geographic Area: | Large River / Lake | Life Stage: | Sub-Adult, Adult |
|---|---|---|---|---|---|

Upstream movement of redband trout is impeded by dams and diversion structures in Kiger and McCoy creeks and the lower Blitzen River. The MNWR operates four diversion dams along the mainstem Blitzen River (Page Springs, Grain Camp, Busse, and Sodhouse). All of these dams are equipped with fish ladders that allow upstream passage, however during certain flows they may cause a delay in migration (Anderson 2009, based on Technical Team input) or temporarily create a complete passage barrier. A USGS flow gauge and weir upstream of Page Springs acts as a partial barrier to redband trout, possibly preventing small fish from moving upstream. This is of particular concern in the summer for fish seeking cold water refuge (Anderson et al. 2011). In the McCoy basin, diversion dams are operated at three points where major irrigation canals or tributaries (collectively referred to as the Diamond Drain) enter the lower mainstem Blitzen River: the Diamond Canal dam and Skunk Farm Canal dam both control water from Kiger and Cucamonga Creeks, and the South Diamond Canal dam controls water from McCoy Creek. These dams are considered to be partial barriers where redband trout can pass downstream but cannot return to upstream spawning grounds (based on Technical Team input, ODFW 2005). In addition, OWRD had record of 42 diversions in the Kiger and McCoy Creek basins (OWRD, unpublished data). Although these records are based on water right certificates and location, passage and screening status still need to be verified, they are indicative of problems associated with fish passage.

Entrainment at these diversion dams is an issue for fish moving downstream where redband trout become entrapped into the irrigation system (based on Technical Team input, USFWS 2012). The MNWR has vertical rotational screens on many of the smaller diversion ditches and canals (USFWS 2012) in addition to the West Canal at Page Springs Dam. The Refuge is in the process of building screens for Highline, Stubblefield, Rheinman and Buena Vista canals. Other ditches will be screened as time and funds allow (USFWS 2012). There is a possibility that fish may also be moving up unscreened irrigation returns on the Refuge, however no information is available to determine the degree to which this occurs (based on Technical Team input). Most diversions on McCoy and Kiger creeks are unscreened (based on Technical Team input).

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## APPENDIX 4

## POTENTIAL EFFECTS OF CLIMATE CHANGE ON REDBAND TROUT

**Potential Effects of Climate Change**

Warming of the global climate regime is unequivocal (IPCC 2007). The previous decade has been the warmest on record, both globally and regionally (IPCC 2007, Chambers 2008). Region-wide warming ranged 0.3 – 0.6°C during the 20th century. Trends in global warming and the accompanying climatic changes are expected to continue in the 21st century at an accelerated rate (Chambers 2008, Mote et al. 2008, Rieman and Isaak 2010). Projections suggest air temperature increases during the next several decades will occur at rates 50-100% faster than in the recent past (Mote et al. 2008) where air temperatures are projected to rise 2 – 5°C over the next century (Cubashi et al. 2001, Chambers 2008). An increase in air temperature will directly translate into increases in stream temperatures through heat transfer, atmospheric radiation and heating of groundwater (OCCRI 2010, Isaak et al. 2011). Stream temperature warming rates could increase by 0.3°C -0.45°C per decade (Isaak et al. 2011). Streams significantly altered by human activities, particularly from the removal of natural riparian vegetation (Moore et al 2005), withdrawal of in-stream flow (Meier et al 2003) and increases in impervious surfaces (Wissmar et al. 2004), will be the most vulnerable to a rise in water temperature.

Warming of air temperatures will also affect the stream hydrograph, particularly in basins with substantial snow accumulations. An increase in winter and spring temperatures will result in a higher proportion of precipitation falling as rain, instead of snow, causing increased winter runoff and reduced water content in the 1 April snowpack (Mote et al. 2005, Hamlet et al 2005). Winter flooding will be more frequent due to rain-on-snow events. Spring high flow will peak earlier because a smaller snow pack will melt sooner in the year (Hamlet et al. 2005). Oregon streams have already experienced a shift in timing where peak flow occurs 10 days earlier (Stewart et al 2004, 2005). Since summer stream flows are typically dependent on snowmelt, climate warming will also cause summer and fall low flows to be lower volume and longer duration (Mote et al 2003, 2005), circumstances that will contribute to both increased stream temperatures and increased water use and withdrawal (OCCRI 2010).

The magnitude of these responses will be highly variable due to differences in topography and basin hydrology. Basins near the snow zone are expected to experience the greatest change where what was once a snowpack dominated flow regime will change to a rain driven system (Mote et al. 2005, Hamlet et al. 2005). Basins above and below this transition area will likely remain as snowmelt and rain dominated, respectively. In the Malheur Lakes basin all watersheds, except Silver Creek, are sensitive to this transition from a snowmelt to rain dominated regime (Hamlet et al. 2008). Silver Creek will remain a rain dominated system. Basins with a strong groundwater influence may be buffered from the effects of warming (OCCRI 2010). Because the groundwater system acts as a reservoir storing seasonally variable recharge, in-stream flows will remain more consistent and potentially cooler (OCCRI 2010). However, in low-order streams the reduction of extended snow-melt may significantly impact flow volume causing perennial streams to become ephemeral (OCCRI 2010).

Terrestrial impacts of global warming also affect in-stream trout habitats. Regional models predict summers will be hotter, drier, and potentially longer (IPCC 2007). These are prime conditions for increased wildfire activity and widespread insect outbreaks (Westerling et al. 2006, Littell et al. 2009). The resulting large-scale alteration or removal of terrestrial plant communities can cause post-fire debris flows and increased sediment loading during high runoff events, which in turn could significantly alter in-stream habitat and hydrologic processes. Impacts of fire and insect outbreaks also provide an increased opportunity for wide spread non-native plant invasion. Statistical models indicate that cheat grass could continue to expand in eastern Oregon with global warming and increased fire frequency

(Bradley 2009). Such changes in the terrestrial plant community may reduce riparian function and streamside shading, further exacerbating the increase of water temperatures.

Climate Change Impacts To Trout

The impacts on redband trout of these projected thermal and hydrologic conditions are potentially extensive. Climate plays a critical role in trout ecology at every life stage and organizational level (e.g. cellular, organism, community) (McCullough et al. 2009, Rieman & Isaak 2010). Climate change effects will be particularly dramatic in populations where key limiting factors include in-stream temperature (water quality) and stream flow (water quantity). While the vagaries of these climate change impacts on specific species are extremely challenging to predict and most are still unexplored, there are some relationships that can be generally described.

Increases in summer stream temperature will affect the distribution and availability of suitable and high quality habitat. Projections estimate suitable habitat for all trout species in the Pacific Northwest will decline 8 – 33% by 2090 (O'Neal et al. 2002). As warming occurs the range of suitable thermal habitats shift from larger, low elevation streams up into smaller, high elevation streams (Jager et al. 1999, Isaak et al. 2010, Wenger et al. 2011a, b). A study in the Boise River Basin between 1993-2006 found rainbow trout habitat shifted up into cold headwater streams but experienced no net gain or loss of stream distance (Isaak et al. 2010). As a result, trout will likely experience habitat loss at the lower distribution limits reducing overall habitat volume and, ultimately, measures of trout biomass (Wenger et al. 2011a, b). In Malheur Lakes, however, the situation differs in that redband trout already occupy many of the colder headwater streams. Suitable habitat is not available for distribution to shift further upstream. The loss of suitable thermal habitat downstream will not only reduce population area, but may also make migratory corridors inaccessible leading to increased fragmentation (Rahel et al. 1996, Williams et al 2009). In addition, in basins where the hydrograph is shifting from a snow-dominated to rain-dominated system, low-order perennial streams may become ephemeral further reducing potential redband trout habitat in the headwaters (OCCRI 2010), decreasing the distribution.

Increased stream temperatures change the metabolic demands of trout, which impacts the scope for growth and significantly influences survival and reproduction. In general, increased water temperatures foster shorter incubation periods and faster growth and maturation of young fish (Beckman et al. 1998, Jager et al. 1999). Faster growth can result in young fish attaining larger size before winter, increasing survival and productivity. However, at stream temperatures above that for optimum growth or in habitats with low ration size, fish will experience higher metabolic costs and the growth of trout will decrease (McCullough et al 2009, Brett et al. 1982, Elliot et al. 1994). Smaller fish suffer lower survival rates and potentially higher pre-spawning mortality, decreasing overall fitness. Similarly, above optimum stream temperatures also compromise egg production, swimming stamina, disease resistance and learning ability (McCullough et al. 2009).

The response of redband trout populations to a changing hydrograph is highly variable, dependent on habitat condition and the timing of flood events in each basin. Wenger et al. (2011a, b) found that rainbow trout in the Rocky Mountains showed a positive response to increased winter flows. Rainbow trout presumably emerged during a period of declining flood probability (Fausch et al. 2001, Wenger et al. 2011a, b) increasing fry survival and productivity. However, in streams lacking sufficient habitat complexity, trout may not find adequate refuge from high winter flows and floods, reducing overwinter survival. In addition, a change in the timing of peak flows may increase egg mortality rates due to dewatering of redds. As the descending limb of the hydrograph occurs earlier, redds constructed during high flows may be dewatered, causing mortality of developing eggs and sac fry (Jager et al. 1999).

The phenology of an individual population is closely tied to environmental conditions. Initiation of migration, spawn timing, egg incubation rates, and fry emergence are closely matched to the hydrograph, temperature regimes and life histories of predator and prey species. A rise in stream temperature, for example, can speed up egg development rates reducing the time between spawning and juvenile hatching. The resulting earlier emergence time may no longer coincide with the availability of prey species (Jager et al. 1999, Brannon 2004). Contributing to this asynchrony is the aquatic invertebrate response to climate change. Invertebrate species will be affected by more variable winter flows that may result in lower biodiversity and abundance of aquatic invertebrates, the primary food source for juvenile trout (OCCRI 2010).

Thermal and hydrologic shifts that accompany climate change are expected to have dramatic impacts on community level interactions such as competition, predation, and food web dynamics. For example, an increase in stream temperature will create conditions where redband trout may be less able to co-exist with warm-water species, many of which are non-native. Warmer stream temperatures will create habitat more suitable to warm-water species potentially increasing their distribution and abundance. At warmer stream temperatures warm-water fish may outcompete redband trout for food and space in interactions where temperature is a mediating factor (DeStaso and Rahel 1994). In addition, predation rates of warm-water species are positively correlated with temperature where consumption of prey is greatest at higher temperatures (Vigg et al. 1991), and redband trout will be less able to avoid predation when thermally stressed (Marine and Cech 2004). The ramifications of global climate change on redband trout and food web dynamics (i.e. algal production, riparian input, macroinvertebrate production and fish predation rates) may be dramatic, but is virtually unknown due to complexities of multispecies interactions. While single species responses can be projected from laboratory studies, the simultaneous species interactions of an entire foodweb is far from being fully understood (McCullough et al. 2009).

While redband trout are well adapted to disturbance regimes of their native systems, the predicted increase in frequency and intensity of wildfire may be detrimental to small, isolated populations. The lack of connection to downstream populations prevents potential for re-colonization (Reiman and Clayton 1997, Greswell 1999). Similarly the inability to migrate to refuge habitats leaves these populations highly vulnerable.

<u>Planning for Climate Change</u>

This plan acknowledges that climate change is not a new phenomenon (OCCRI 2010). Current redband trout distribution in the Great Basin is shaped by over 70,000 years of change in climatic conditions. Redband trout have adapted to changing and variable environments through phenotypic plasticity and mechanisms of natural selection. However, the rapid rate of climatic change and habitat degradation caused by humans may interfere with their ability to respond quickly enough to persist. Redband trout capacity to evolve may simply be out paced by the rate of a changing climate (Rieman and Isaak 2010).

While the general implications of climate change to aquatic communities are readily accepted, the specific impacts are uncertain due to the complex interaction of the physical, biological and ecological processes that lead to a multitude of indirect effects. These effects are important but very difficult to anticipate. The interaction of climate change, heterogeneous landscapes, shifting species distribution and new biotic and physical interactions will create novel environments, trophic cascades and communities that have no natural precedent (Rieman & Isaak 2010). As a result it is not practical for this conservation plan to identify specific actions that directly address impacts of climate change. Instead guidelines outlined in the plan are intended to foster resistance to rapid environmental change and resilience to disturbance. The plan's general approach is to:

1) protect the remaining populations and habitat strongholds,
2) maintain genetic and life history diversity,
3) maintain current distribution and abundance (increase if possible) through habitat and riparian restoration to offset significant warming (Isaak et al 2011a),
4) reconnect fragmented populations or streams through barrier removal or increasing in-stream flow to provide the ability to shift distributions and track thermal habitat (Fausch et al 2006, Isaak et al 2011a)
5) curtail current population stressors, and
6) Increase population monitoring (Williams 2007).

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