Species Status Assessment Report
for the
Rio Grande Cutthroat Trout

Photo courtesy of Colorado Parks and Wildlife

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Suggested reference:

U.S. Fish and Wildlife Service. 2014. Species status assessment report for the Rio Grande cutthroat trout. Albuquerque, NM.

EXECUTIVE SUMMARY

This species status assessment reports the results of the comprehensive status review for the Rio Grande cutthroat trout (*Oncorhynchus clarkii virginalis*) and provides a thorough account of the subspecies' overall viability and thus extinction risk. Rio Grande cutthroat trout (a subspecies of cutthroat trout) inhabit high elevation streams in New Mexico and southern Colorado where they need clear, cold, highly oxygenated water, clean gravel substrates, a network of pools and runs, and an abundance of food (typically aquatic and terrestrial invertebrates) to complete their life history.

The Rio Grande cutthroat trout needs multiple resilient populations widely distributed across its range to maintain its persistence into the future and to avoid extinction. Resilient populations require long continuous suitable stream habitats to support large numbers of individuals and to withstand stochastic events; the populations should be free from the impacts of nonnative trout. The resilient populations should be distributed in each of the four Geographic Management Units (GMUs) where the subspecies currently occurs. This distributional pattern will provide for the needed redundancy and representation to increase the probability that the subspecies will withstand future catastrophic events and maintain future adaptive capacity in terms of genetic and ecological diversity. The population and subspecies-level needs for viability of the Rio Grande cutthroat trout are summarized in column 2 of Table ES-1. The likelihood of the Rio Grande cutthroat trout's persistence depends upon the number of populations, its resilience to threats, and its distribution. As we consider the future viability of the subspecies, more populations with greater resiliency and wider geographic distributions are associated with higher overall subspecies viability.

The Rio Grande cutthroat trout historically occurred in New Mexico and southern Colorado. Its distribution has been divided into GMUs reflecting major hydrologic divisions. The subspecies no longer occurs in one GMU, the Caballo GMU, where only one population was historically known. The remaining four GMUs are managed by the States of Colorado and New Mexico and other agencies as separate units to maintain genetic and ecological diversity within the subspecies where it exists and to ensure representation of the subspecies across its historical range. GMUs were not created to necessarily reflect important differences in genetic variability, although fish in the Pecos and Canadian GMUs do exhibit some genetic differentiation from those in the Rio Grande basin GMUs. From a rangewide perspective, multiple Rio Grande cutthroat trout populations should be dispersed throughout the various GMUs to maintain subspecies viability, reduce the likelihood of extinction, and provide the subspecies with redundancy.

Table ES-1. Overall summary of species status assessment for Rio Grande cutthroat trout. ("RG" = Rio Grande, "pop's" = populations)

3 R's	NEEDS	CURRENT CONDITION	FUTURE CONDITION (VIABILITY)
Resiliency: Population ***(large populations to withstand stochastic events)***	• Large Effective Population Sizes (effective population sizes >500 are best). • Long Streams for Habitat (streams greater than 9.65 km are best). • Free of Nonnative Trout (mainly rainbow and brown trout) and Disease (whirling). • High Quality Habitat (water temps < critical summer maximums).	• 122 Extant Populations across range. * 55 (45%) of populations are currently in the best or good condition *(based on absense of nonnative trout, effective population size, and occuppied stream length)* * 67 (55%) of populations are currently in fair or poor condition.	• Status assessment model estimates probability of persistence for each population based on risks from: * Effective Population Size. * Nonnatives (hybridization, competition) and Disease. * Wildfire and Stream Drying . * Water Temperature Increase. • Included climate change considerations for increased risks.
Resiliency: Subspecies ***(populations to withstand stochastic events)***	• Multiple interconnected resilient populations.	• About 11% of historic range remains occupied due to past impacts from nonnatives. • Populations are isolated (16 populations have some connectedness).	• 2080 model forecasts future populations persisting; results range depending on future management level and severity of climate change: reporting **best to worst (intermediate)** results: * **50 to 132 (69)** populations rangewide. • Limited opportunity to regain interconnectedness of populations (due to pervasive nonnative trout).
Redundancy ***(number and distribution of populations to withstand catostrophic events)***	• Multiple highly resilient populations within each of the 4 Geographic Management Units (GMUs).	• Current total number of populations persisting by GMU: * 41 pop's in RG Headwaters GMU. * 59 pop's in Lower RG GMU. * 10 pop's in Canadian GMU. * 12 pop's in Pecos GMU.	• 2080 model forecasts for future populations persisting by GMU: * **21 to 55 (27)** pop's in RG Headwaters. * **21 to 47 (28)** pop's in Lower RG. * **3 to 14 (6)** pop's in Canadian. * **5 to 16 (8)** pop's in Pecos.
Representation ***(genetic and ecological diverstiy to maintain adaptive potential)***	• Genetic variation exists between 1) Two GMUs in the Rio Grande Basin and 2) Two GMUs in Canadian and Pecos River Basins. • Unknown ecological variation, but we used GMUs as proxy.	• Current total populations persisting by Watershed: * 100 pop's in Rio Grande Basin. * 22 pop's in Candadian and Pecos GMUs.	• 2080 model forecasts for future populations persisting by watershed: * **42 to 102 (55)** pop's in Rio Grande Basin. * **8 to 30 (14)** pop's in Canadian and Pecos GMUs.

Currently the subspecies is distributed in 122 populations across the four extant GMUs (ranging from 10 to 59 populations per GMU), and most of the populations are isolated from other populations. The total amount of currently occupied stream habitat is estimated to be about 11% of the historically occupied range. This large decline in distribution and abundance is primarily due to the impacts of the introduction of nonnative trout. Nonnative rainbow trout (*O. mykiss*) and other nonnative subspecies of cutthroat trout have invaded most of the historical range of the Rio Grande cutthroat trout and resulted in their extirpation because the nonnative trout readily hybridize with Rio Grande cutthroat trout. In addition, brown trout (*Salmo trutta*) and brook trout (*Salvelinus fontinalis*) have also displaced Rio Grande cutthroat trout in some historical habitats through competition and predation pressures. We evaluated the current condition of the 122 populations and categorized the condition of each population based on the absence of nonnative trout, the effective population size, and the occupied stream length. Fifty-five populations were in either the "best" or "good" condition in this categorization. Table ES-2 identifies the number populations placed in each category by GMU (see Chapter 3 for a description of the categories).

Table ES-2. Current status of Rio Grande cutthroat trout showing the number of current conservation populations in 4 categories by GMU. The percentages (%) are the proportion of total populations within each GMU.

Populations per GMU	Best	%	Good	%	Fair	%	Poor	%	Total
Canadian	1	10%	3	30%	5	50%	1	10%	10
Rio Grande Headwaters	5	12%	14	34%	20	49%	2	5%	41
Lower Rio Grande	13	22%	15	25%	20	34%	11	19%	59
Pecos	1	8%	3	25%	7	33%	1	42%	12
Rangewide	20	16%	35	29%	52	43%	15	12%	122

We next reviewed the past, current, and future factors that could affect the persistence of Rio Grande cutthroat trout populations. Seven risk factors were evaluated in detail to estimate their individual and cumulative contributions to the overall risk to the subspecies' viability. We focused on these seven factors because they were found to potentially have population-level effects on the subspecies. The seven factors were:

(1) **Demographic Risk:** Small population sizes are at greater risk from inbreeding, demographic fluctuations, and reduced genetic diversity, and they are more vulnerable to extirpation from other risk factors.

(2) Hybridizing Nonnative Trout: Nonnative rainbow and other cutthroat trout subspecies have historically been introduced throughout the range of Rio Grande cutthroat trout for recreational angling, and they are known to readily hybridize with Rio Grande cutthroat trout. Climate change may exacerbate this risk factor as warmer waters may make high elevation habitats more susceptible to invasion by rainbow trout.

(3) Competing Nonnative Trout: Brook and brown trout compete with Rio Grande cutthroat trout for food and space, and larger adults will prey upon young Rio Grande cutthroat trout.

(4) Wildfire: Ash and debris flows that occur after a wildfire can eliminate populations of fish from a stream, and wildfires within the range of Rio Grande cutthroat trout have depressed or eliminated fish populations. As drought frequency increases due to climate change, dry forests are more likely to burn and burn hotter than they have in the past.

(5) Stream Drying: Drying of streams occupied by Rio Grande cutthroat trout may occur as a result of drought or, in a few cases, water withdrawals. Drought frequency is expected to increase as a result of climate change due to a combination of increased summer temperatures and decreased precipitation.

(6) Disease: Whirling disease damages cartilage, killing young fish or causing infected fish to swim in an uncontrolled whirling motion, making it impossible to avoid predation or feed.

(7) Water Temperature Changes: Changes in air temperature and precipitation patterns expected from climate change could result in elevated stream temperatures that make habitat unsuitable for Rio Grande cutthroat trout to complete their life history.

We considered other potential factors as well, including hydrologic changes related to future climate change, effects to habitat related to land management, and angling. Our review of the best available information did not demonstrate a relationship between hydrologic changes and the effects on the subspecies to allow for reasonably reliable conclusions; therefore, we did not consider that factor further. We found that land management activities are not likely to have a measurable population-level effect on the subspecies, and angling was also not found to be a substantial factor affecting the subspecies. Therefore, these factors were not evaluated further in our analysis.

We included future management actions as an important part of our overall assessment. The Rio Grande Cutthroat Trout Rangewide Conservation Team (Conservation Team) is composed of biologists from Colorado Parks and Wildlife (CPW), New Mexico Department of Game and Fish (NMDGF), U.S. Bureau of Land Management (BLM), U.S. Forest Service (USFS), National Park Service (NPS), Mescalero Apache Nation, Jicarilla Apache Nation, Taos Pueblo, and the Service. The Conservation Team developed the Conservation Agreement and Strategy in 2013 (revised from the previous Conservation Agreements in 2003 and 2009), which formalized many ongoing management actions. The Conservation Agreement and Strategy includes activities such as stream restorations, barrier construction and maintenance, nonnative species removals, habitat improvements, public outreach, and database management. Over the 10-year life of the Conservation Agreement and Strategy, the Conservation Team has committed to restoration of between 11 and 20 previously extirpated Rio Grande cutthroat trout populations to historical habitat. We included these activities in our analysis of the future status of the subspecies over the next 10 years and projected various scenarios of active management beyond that.

We developed a species status assessment model to quantitatively incorporate the risks of extirpation from the seven risk factors listed above (including cumulative effects) in order to estimate the future probability of persistence of each extant population of Rio Grande cutthroat trout. We used this model to forecast the future status of the Rio Grande cutthroat trout in a way that addresses viability in terms of the subspecies' resiliency, redundancy, and representation. As a result we developed two distinct modules. Module 1 estimates the probability of persistence for each Rio Grande trout population by GMU for 3 time periods (2023, 2040, and 2080) under a range of conditions, and Module 2 estimates the number of surviving populations by GMU for three time periods under several scenarios related to future management actions and the effects of climate change. A detailed explanation of the methodology used to the develop the model is provided in Appendix C, and the results are summarized in Chapter 5. The results of the analysis for three scenarios in 2080 are listed in Column 4 of Table ES-1.

We used the results of this analysis to describe the Rio Grande cutthroat trout viability (viability is the ability of a species to persist over time and thus avoid extinction; "persist" means that the species is expected to sustain populations in the wild beyond the end of a specified time period) by characterizing the status of the species in terms of its resiliency, redundancy, and representation.

Resiliency is having sufficiently large populations for the subspecies to withstand stochastic events. We measured resiliency at the population scale for the Rio Grande cutthroat trout by quantifying the persistence probability of each extant population under a range of assumed conditions. As expected, because the status assessment model was developed to forecast linearly increasing risks over time, all of the population persistence probabilities decrease in our three time periods. Our results do not necessarily mean that any one population will, in fact, be extirpated by 2080; they simply reflect the risks that we believe the populations face due to their current conditions and the risk factors influencing their resiliency.

Rangewide, the resiliency of the subspecies has declined substantially due to the large decrease in overall distribution in the last 50 years. In addition, the remnant Rio Grande cutthroat trout populations are now mostly isolated to headwater streams due to the fragmentation that has resulted from the historical, widespread introduction of nonnative trout across the range of Rio Grande cutthroat trout. Therefore, if an extant population is extirpated due to a localized event, such as a wildfire and subsequent debris flow, there is little to no opportunity for natural recolonization of that population. This reduction in resiliency results in a lower probability of persistence for the subspecies as a whole. To describe the remaining resiliency of the subspecies, we evaluated the individual populations in detail to understand the subspecies' overall capacity to withstand stochastic events.

Redundancy is having a sufficient number of populations for the subspecies to withstand catastrophic events. For the Rio Grande cutthroat trout, we measured redundancy based on our forecasting of the number of populations persisting across the subspecies' range. The results suggest that, depending on the particular scenario related to risk factors and restoration efforts, the overall number of populations may decline to some extent by 2080 (see Table ES-1, Column 4). We are focusing on the estimates for 2080, because if the subspecies has sufficient redundancy by 2080, it will also have sufficient redundancy in the more recent time periods. Rangewide there are currently 122 populations, and we forecast between 50 and 132 populations surviving in 2080 (with an intermediate forecast of 68 populations). The wide range in the estimated number of surviving populations is due to the various projections of management and climate change intensity. Some GMUs may decline more than others; for example, our forecasts suggest the Lower Rio Grande GMU may have the largest decline. We estimate the current 59 populations in this GMU could be between 21 and 47 populations by 2080 (with an intermediate forecast of 28 populations). The GMU with the least populations, the Canadian GMU, is forecasted to change from 10 current populations to between 3 and 14 populations by 2080 (with an intermediate forecast of 6 populations).

Representation is having the breadth of genetic and ecological diversity of the subspecies to adapt to changing environmental conditions. For the Rio Grande cutthroat trout, we evaluated representation based on the extent of the geographical range expected to be maintained in the future as indicated by the populations occurring within each GMU for a measure of ecological diversity. For genetic diversity, there are important genetic differences between the Rio Grande basin populations and the populations in the Canadian and Pecos GMUs (though the Pecos and Canadian GMUs are not genetically different from each other). The variation in persistence probabilities is distributed across the GMU so that none of the risk is particularly associated with any particular geographic area within the GMU. Combined, the Canadian and Pecos GMUs are forecasted to have 8 to 30 populations surviving in 2080 (with an intermediate forecast of 14 populations).

We used the best available information to forecast the likely future condition of the Rio Grande cutthroat trout. Our goal was to describe the viability of the subspecies quantitatively in a way that characterizes the needs of the subspecies in terms of resiliency, redundancy, and representation. We considered the possible future condition of the subspecies out to about 65 years from the present. We considered nine different scenarios that spanned a range of potential conditions that we believe are important influences on the status of the subspecies. Our results describe a range of possible conditions in terms of the probability of persistence of individual populations across the GMUs and a forecast of the number of populations surviving in each GMU.

None of our "worst case scenario" forecasts result in a predicted loss of all of the populations within any of the GMUs. Therefore, at a minimum, our results suggest the subspecies will have persisting populations in 2080 across its range. Most of the scenarios generally show a declining persistence and number of populations over time. However, the rate of this decline, or whether it occurs at all, depends largely on the likelihood of future management actions occurring, the most important of which are the future restoration and reintroduction of populations within the historical range and the control of nonnative trout. While other factors are important to each population, the future management actions will probably determine the future viability of the Rio Grande cutthroat trout.

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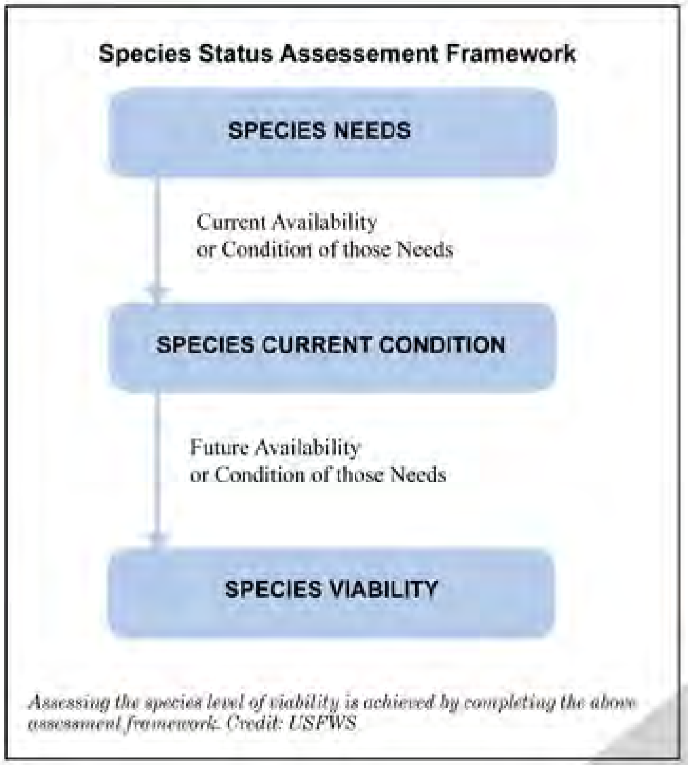
Chapter 1. Introduction

The Rio Grande cutthroat trout (*Oncorhynchus clarkii virginalis*) lives in high elevation, coldwater streams in New Mexico and southern Colorado. It is a subspecies that was made a candidate for listing in 2008 by the U. S. Fish and Wildlife Service (Service) under the Endangered Species Act of 1973, as amended (Act) (73 FR 27900, May 14, 2008). It is now being reviewed for listing as a threatened or endangered species under the Act. This Rio Grande cutthroat trout Species Status Assessment Report (SSA Report) is a summary of the information assembled and reviewed by the Service and incorporates the best scientific and commercial data available. This SSA Report documents the results of the comprehensive status review for the Rio Grande cutthroat trout.

The Service is engaged in a number of efforts to improve the implementation of the Act (see www.fws.gov/endangered/improving_ESA). The priority of the Service is to make implementation of the Act less complex, less contentious, and more effective. As part of this effort, our Endangered Species Program has begun to develop a new framework to guide how we assess the biological status of species (and in this case, subspecies). Because biological status assessments are frequently used in all of our Endangered Species Program areas, developing a single, scientifically sound document is more efficient than compiling separate documents for use in our listing, recovery, and consultation programs. For example, much of the information we gather on species needs within an assessment can provide a basis for recovery criteria during recovery planning. Moreover, we can also use the analysis of risks a species is facing to conduct endangered species consultations, particularly if we determine how conservation measures could be employed to minimize or avoid effects of a proposed action. Therefore, we have developed the following SSA Report that contains summary information regarding life history, biology, and consideration of current and future risk factors facing the Rio Grande cutthroat trout.



Assessing the species level of viability is achieved by completing the above assessment framework. Credit: USFWS

The objective of the SSA is to thoroughly describe the viability of the Rio Grande cutthroat trout. Through this description, we will determine what the subspecies needs to remain viable, its current condition in terms of those needs, and its forecasted future condition. In conducting this analysis we take into consideration the changes that are happening in the environment – past, current, and future – to help us understand what factors drive the viability of the subspecies.

For the purpose of this assessment, we define **viability** as a description of the ability of a species (in this case subspecies) to persist over time and thus avoid extinction. "**Persist**" and "**avoid extinction**" mean that the species is expected to sustain populations in the wild beyond the end of a specified time period. Using the SSA framework, we consider what the species needs to maintain viability by characterizing the status of the species in terms of its **resiliency**, **redundancy**, and **representation**.

• **Resiliency** is having sufficiently large populations for the subspecies to withstand stochastic events. Stochastic events are those arising from random factors such as weather, flooding, or fire. We can measure resiliency based on metrics of population health; in the case of the Rio Grande cutthroat trout, population size, habitat size, and freedom from nonnative trout species are primary indicators of resiliency. Resilient populations are better able to withstand disturbances such as random fluctuations in birth rates (demographic stochasticity), variations in rainfall (environmental stochasticity), or the effects of wildfire.

• **Redundancy** is having a sufficient number of populations for the subspecies to withstand catastrophic events. A catastrophic event is defined here as a rare destructive event or episode involving many populations and occurring suddenly. Redundancy is about spreading risk and can be measured through the duplication and broad distribution of resilient populations across the range of the subspecies. The more resilient populations the subspecies has, distributed over a larger landscape area, the better chances that the subspecies can withstand catastrophic events. For the Rio Grande cutthroat trout, we measure redundancy based on the number of populations persisting across the subspecies' range.

• **Representation** is having the breadth of genetic makeup of the subspecies to adapt to changing environmental conditions. Representation can be measured through the genetic diversity within and among populations and the ecological diversity (also called environmental variation or diversity) of populations across the subspecies' range. The more representation, or diversity, the subspecies has, the more it is capable of adapting to changes (natural or human caused) in its environment. In the case of the Rio Grande cutthroat trout, we evaluate representation based on the extent of the geographical range measured by the populations occurring within Geographic Management Units (GMUs) (see 3.1 Historical Range and Distribution for more information about GMUs) as an indicator of genetic or ecological diversity.

To evaluate the viability of the Rio Grande cutthroat trout both currently and into the future we assessed a range of conditions to allow us to consider the subspecies' resiliency, redundancy, and representation. This SSA Report provides a summary assessment of Rio Grande cutthroat trout biology and natural history and assesses the risks to its future viability. Herein, we summarize biological data and a description of past, present, and likely future risk factors facing the Rio Grande cutthroat trout.

The format for this SSA Report includes: (1) the resource needs of individuals (Chapter 2); (2) the Rio Grande cutthroat trout's historical distribution and a framework for what the subspecies needs in terms of the number and distribution of resilient populations across its range for subspecies viability (Chapter 3); (3) reviewing the likely causes of the current and future status of the subspecies, and determining which of these risk factors affect the subspecies' viability and to what degree (Chapter 4); and (4) concluding with a quantitative description of the viability in terms of resiliency, redundancy, and representation (Chapter 5). This document is a compilation of the best available scientific and commercial information and a description of past, present, and likely future threats to the Rio Grande cutthroat trout.

For a glossary of some of the terms used in this SSA Report, reference Appendix A. The detailed analysis of risk factors summarized in Chapter 4 is found in Appendix B. Finally, we conducted an analysis to quantitatively characterize the viability of the Rio Grande cutthroat trout as described in Appendix C. Our objectives for this Status Assessment Model were twofold: (1) to estimate the probability of persistence of each extant Rio Grande cutthroat trout population over time; and (2) to describe the future persistence of Rio Grande cutthroat trout by forecasting the number of populations expected to persist across the subspecies' range over time. Finally, the literature cited in this SSA Report is in Appendix D[1].

We primarily used information from the Rio Grande cutthroat trout rangewide database (RGCT Database) from 2013, which includes data from 2012. This is the most recent database available (see section 2.5, Management History of Rio Grande Cutthroat Trout, for more information about the RGCT Database). We supplemented information from the RGCT Database based on new information received from various sources, including communications with Rio Grande cutthroat trout biologists from the states of Colorado and New Mexico. We also relied heavily on the prior work completed for the most recent rangewide assessment for the Rio Grande cutthroat trout (Alves *et al.* 2008).

Importantly, this SSA Report does not result in, or predetermine, a decision by the Service on whether the Rio Grande cutthroat trout warrants protections of the Act, or whether it should be proposed for listing as a threatened or endangered species under the Act. That decision will be made by the Service after reviewing this document, along with the supporting analysis, other relevant scientific information, and all applicable laws, regulations, and policies, and the results of the decision will be announced in the *Federal Register*. Instead, this SSA Report provides a strictly scientific review of the available information related to the biological status of the Rio Grande cutthroat trout.

[1] We did not cite every report and information source that was reviewed for this assessment. Only the cited sources are referenced in this SSA Report.

Chapter 2. Individual Needs: Life History and Biology

In this chapter we provide basic biological information about the Rio Grande cutthroat trout, including its taxonomic history, morphological description, and known life history traits. We then outline the resource needs of individuals and populations of the Rio Grande cutthroat trout. There are numerous sources of information on Rio Grande cutthroat trout life history and biology (*e.g.,* Cowley 1993; Behnke 2002; New Mexico Department of Game and Fish (NMDGF) 2002; Pritchard and Cowley 2006). Here we report those aspects of the subspecies' life history that are important to our analysis. Finally, we discuss the management history of the subspecies.

2.1 Taxonomy

In 1541, Francisco de Coronado's expedition in the upper Pecos River discovered Rio Grande cutthroat trout, one of 14 subspecies of cutthroat trout (Behnke 2002, p. 207). Figure 1 shows a generalized range of Rio Grande cutthroat trout, as well as other proximal cutthroat trout subspecies and other native trout.

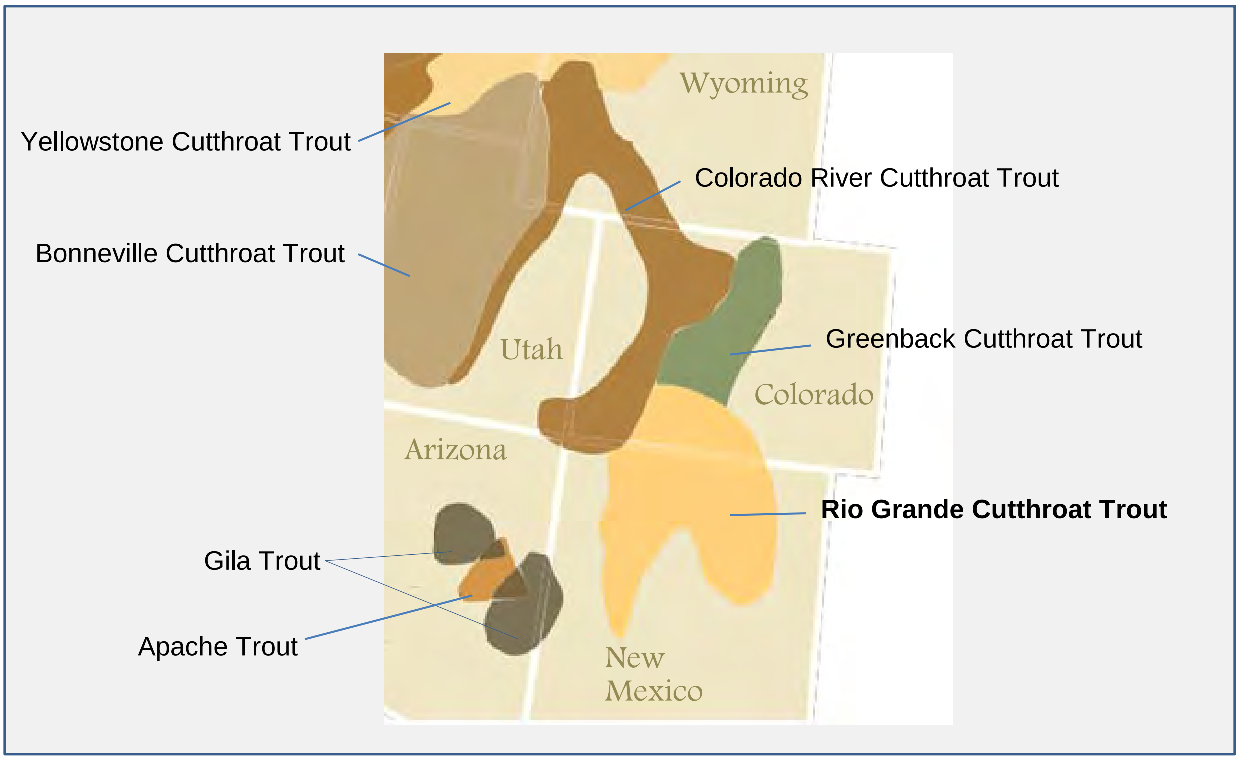


Figure 1. Generalized map of Rio Grande cutthroat trout distribution in relation to other nearby cutthroat trout subspecies, as well as other species of native trout. Map adapted from Western Native Trout Initiative 2008.

The first specimens that were collected for scientific purposes came from Ute Creek in Costilla County, Colorado, in 1853. Rio Grande cutthroat trout was originally described in 1856 (Behnke 2002, p. 210). The currently accepted subspecies classification is:

Class: Actinopterygii
Order: Salmoniformes
Family: Salmonidae
Species: *Oncorhynchus clarkii virginalis* Girard, 1856

2.2 Subspecies Description

Cutthroat trout are distinguished by the red to orange slashes in the folds beneath the lower jaw (Behnke 2002, p. 139) (Figure 2). Rio Grande cutthroat trout have irregular shaped spots that are concentrated behind the dorsal fin, smaller less numerous spots located primarily above the lateral line in front of the dorsal fin, and basibranchial teeth that are minute or absent (Sublette *et al.* 1990, p.53; Behnke 2002, p. 207). Rio Grande cutthroat trout are light rose to red-orange on the sides and pink or yellow-orange on the belly (Behnke 2002, p. 207).

Figure 2. Rio Grande cutthroat trout from the Lake Fork Conejos River, Colorado. Photo courtesy of Colorado Parks and Wildlife.

2.3 Life History

Rio Grande cutthroat trout exhibit a life history similar to other cutthroat trout subspecies. Adults spawn as high water flows from snowmelt recede, which typically occurs from the middle of May to the middle of June (NMDGF 2002, p. 17). Spawning is believed to be tied to day length, water temperature, and runoff (Sublette *et al*. 1990, p. 54; Behnke 2002, p. 141). It is unknown if Rio Grande cutthroat trout spawn every year or if some portion of the population spawns every other year as has been recorded for westslope cutthroat trout (*O. c. lewisi*) (McIntyre and Rieman 1995, p. 1). Likewise, while it is assumed that females mature at age 3, they may not spawn until age 4 or 5 as seen in westslope cutthroat trout (McIntyre and Rieman 1995, p. 3). Individuals greater than 120 millimeters (mm) (4.7 inches (in)) are considered adults (Pritchard and Cowley 2006, p. 25). Adults have been observed as old as 8 years (Pritchard and Cowley 2006, p. 30).

A female constructs the nest (redd) just prior to spawning and deposits 200 – 4,500 eggs in it, which are then fertilized by a male (Cowley 1993, p. 3). Rio Grande cutthroat trout do not exhibit parental care of the redd or young. Depending on water temperature, the eggs hatch within 3 – 7 weeks (Prichard and Cowley 2006, p. 26). The hatchlings remain within the gravel of the redd for several weeks until the yolk sac is absorbed (Pritchard and Cowley 2006, p. 26). Sex ratio also is unknown with certainty, but based on field data, a ratio skewed towards more females might be expected (Pritchard and Cowley 2006, p. 27).

Although Yellowstone (*O. c. bouvieri*) (Gresswell 1995, p. 36), Bonneville (*O. c. utah*) (Schrank and Rahel 2004, p. 1532), and westslope (Bjornn and Mallet 1964, p. 73; McIntyre and Rieman 1995, p. 3) cutthroat trout subspecies are known to have a migratory life history phase, in which the trout will move between lakes and rivers, it is not known if Rio Grande cutthroat trout once had a migratory form when there was connectivity among watersheds. There are no migratory populations today.

Most cutthroat trout are opportunistic feeders, eating both aquatic invertebrates and terrestrial insects that fall into the water (Sublette *et al*. 1990, p. 54). As individuals grow they may exhibit more benthic feeding (Pritchard and Cowley 2006, p. 25). Cutthroat trout subspecies generally become more piscivorous (fish eating) as they mature (Sublette *et al.* 1990, p. 54). Growth of cutthroat trout varies with water temperature and availability of food. Because most populations of Rio Grande cutthroat trout are currently found in high elevation streams, growth may be relatively slow and time to maturity may take longer than is seen in subspecies that inhabit lower elevation, warmer streams.

2.4 Resource Needs (Habitat) of Individuals

As is true of other subspecies of cutthroat trout, Rio Grande cutthroat trout are found in clear, cold, high elevation streams. Much of what is known of Rio Grande cutthroat trout life history is from studies of other cutthroat trout subspecies, and we presume that this knowledge applies to Rio Grande cutthroat trout. Rio Grande cutthroat trout require several types of habitat for survival: spawning habitat, nursery or rearing habitat, adult habitat, and refugial habitat (organized by life stage in Table 1). Rio Grande cutthroat trout spawn as floods from snowmelt runoff recede. Spawning habitat is found in areas exposed to flowing water with clean gravel (little or no fine sediment present) that ranges between 6 – 40 millimeters (mm) (0.24 – 1.6 inches (in)) in diameter (NMDGF 2002, p. 17; Budy *et al.* 2012, p. 437, 447) where redds are formed (Cowley 1993, p. 3). Embryonic development of cutthroat trout within eggs requires flowing water with high oxygen levels (Cowley 1993, p. 3; Budy *et al*. 2012, p. 437). Fry emerge after yolk absorption and at a length of about 20 mm (0.8 in) (McIntyre and Rieman 1995, p. 2).

Following emergence, cutthroat trout fry move to nursery habitat, usually stream margins, backwaters, or side channels where water velocity is low and water temperature is slightly warmer (Pritchard and Cowley 2006, pp. 17–18). Drifting and benthic invertebrates, upon which trout feed, are frequently numerous in such areas (Pritchard and Cowley 2006, p. 18). Fry establish individual territories in these habitats, generally near a source of cover such as aquatic plants or overhanging vegetation, and remain in them for several months (Pritchard and Cowley

2006, p. 18). Juvenile cutthroat trout use stream substrate as cover during winter (McIntyre and Rieman 1995, p. 4). Water temperature is important for juvenile survival; streams with mean daily temperatures in July of less than 7.8 degrees Celsius (ºC) (46 degrees Fahrenheit (ºF)) may not have successful reproduction or recruitment (survival of individuals to sexual maturity and joining the reproductive population) in most years (Harig and Fausch 2002, pp. 542, 543; Coleman and Fausch 2007a, p. 1241; Coleman and Fausch 2007b, p. 651). Recent studies have shown that Rio Grande cutthroat trout have similar thermal tolerances as other subspecies of cutthroat trout. When water temperatures mimic natural daily fluctuations (warmer during the day, cooler at night), Rio Grande cutthroat trout can tolerate up to 25 ºC (77 ºF) (Zeigler *et al*. 2013a, p. 1400). Chronic effects of high temperatures, such as declining growth rates of individuals, have been observed when 30-day average temperatures exceed 18 ºC (64 ºF) (Zeigler *et al.* 2013a, p. 1400).

As Rio Grande cutthroat trout grow, they move back into the main stream channel. Older individuals primarily use pools with cover and riffles for foraging (Pritchard and Cowley 2006, p. 18). Deep pools that do not freeze in the winter and do not dry in the summer or during periods of drought provide refugia. Lack of large pools may be a limiting factor in headwater streams (Harig and Fausch 2002, p. 543). Refugial habitat may also be a downstream reach of stream or a connected adjacent stream that has maintained suitable habitat in spite of adverse conditions that eliminated or reduced habitat from the rest of the stream. For populations to persist, Rio Grande cutthroat trout must be able to disperse to and from these habitats (Fausch *et al.* 2002, p. 494).

Table 1. Known habitat needs of Rio Grande cutthroat trout by life stage.

Life Stage	Resource Needs (Habitat)	References
Eggs – Emergence of Fry - **May to June**	• Flowing water (mean water column velocities between 0.11–0.90 m/sec, with optimal velocities between 0.30 – 0.60 m/sec), with clean gravel (6 – 40 mm diameter) • Water with high dissolved oxygen levels (>7 milligrams per liter (mg/L) at ≤15 °C and ≥9 mg/L at >15 °C). • Water temperature between 6 – 17 °C (43 – 63 °F), optimal 10 °C (50 °F)	NMDGF 2002, p. 17 Budy *et al*. 2012, p. 437, 447 Budy *et al*. 2012, p. 437 Budy *et al*. 2012, p. 437, 446 Zeigler *et al*. 2013a, p. 1399
Fry - **summer through fall**	• Stream margins, backwaters, or side channels. • Benthic invertebrates • Low water velocities • Water temperatures above 7.8 °C (46 °F)	Pritchard and Cowley 2006, pp. 17 – 18 Cowley 1993, p. 3 Sublette *et al*. 1990, p. 4 Harig and Fausch 2002, pp. 542, 543 Coleman and Fausch 2007a, p. 1241 Coleman and Fausch 2007b, p. 651
Juveniles (<120 mm Total Length (TL)) - **Year 1-2**	• Mean water temperatures ideally >7.8 °C (46 °F) and <18 °C (64 °F) • Instream cover for winter	Harig and Fausch 2002, pp. 542, 543 Gard 1963, p. 197 Zeigler *et al*. 2013a, p. 1400 Coleman and Fausch 2007a, p. 1241 Coleman and Fausch 2007b, p. 651
Adults (>120 mm TL) - **Year ~3+**	• Deep water pools (> 30 centimeters (cm) (12 inches (in)) • Prey in the form of invertebrates and in some cases small fish • Mean water temperatures ideally >7.8 °C (46 °F) and <18°C (64 °F)	Harig and Fausch 2002, p. 543 Young *et al*. 2005, p. 2402 Pritchard and Cowley 2006, p. 18 Zeigler *et al*. 2013a, p. 1400

2.5 Management History of Rio Grande Cutthroat Trout

Cooperative efforts between New Mexico, Colorado, Federal agencies, Tribes, and nongovernmental organizations (NGOs) to manage and conserve Rio Grande cutthroat trout have been ongoing for decades. Due in large part to interest in the Rio Grande cutthroat trout for recreational angling, the States of New Mexico and Colorado have long had an interest in managing populations and conducting research on the subspecies, and they have led management efforts for many years to restore populations and improve habitat. In 2003, the first Conservation Agreement was signed, and the Rio Grande Cutthroat Trout Conservation Team was formed. This Team is comprised of representatives of the signatory agencies (including States, Federal agencies, Tribes, and NGOs), as well as members of academia. The Conservation Team developed the RGCT Database, which houses all data collected on populations, including management actions, surveys, and other information. The Conservation Agreement was renewed in 2009 and again in 2013. Further, in 2008 the Conservation Team released its Status Assessment of the Rio Grande Cutthroat Trout (Alves *et al*. 2008), which summarized the current conditions of the trout, based on information from the RGCT Database. We rely on information from this Status Assessment often throughout this SSA Report.

In 2013, the Conservation Team developed the Rio Grande Cutthroat Trout Conservation Strategy (RGCT Conservation Team 2013), which is a signed 10-year commitment to implement ongoing conservation actions. The development of this Strategy was directed by the Conservation Agreement. These actions include reintroduction of 11 – 20 populations, habitat improvement, barrier construction and maintenance, and nonnative fish removals. Annual coordination meetings will continue to occur to review prior actions and to plan upcoming actions. These actions take place rangewide across all GMUs.

Also in 2013, Vermejo Park Ranch signed a Candidate Conservation Agreement with Assurances (Vermejo CCAA) with the Service and the States of Colorado and New Mexico. When completed, this project is expected to increase occupied stream miles by approximately 20% and create a large, interconnected population of over 75,000 individuals throughout over 100 stream miles (Kruse 2013, p. 2). The project is currently 50% completed and is expected to be fully completed by 2020.

Chapter 3. Population and Subspecies Needs and Current Conditions

In this chapter we consider the Rio Grande cutthroat trout's historical distribution and what the subspecies needs in terms of the number and distribution of resilient populations across its range for the subspecies as a whole to be viable. We first review the historical information on the range and distribution of populations of the subspecies. We next review the conceptual needs of the subspecies, including population resiliency, redundancy, and representation to maintain viability and reduce the likelihood of extinction. Finally, we consider the current conditions of all Rio Grande cutthroat trout populations rangewide.

3.1 Historical Range and Distribution

Rio Grande cutthroat trout are generally assumed to have occupied all streams capable of supporting trout in the Rio Grande, Pecos, and Canadian basins (Alves *et al*. 2007, p. 9). The Pecos River is a tributary of the Rio Grande, so a historical connection between the two basins likely existed. Although no early museum specimens document its occurrence in the headwaters of the Canadian River, there is no evidence of human introduction and so it is almost certainly native there as well (Behnke 2002, p. 208; Pritchard *et al.* 2009, p. 1219). The Canadian River, which drains to the Mississippi River basin, has no connection with the Rio Grande. It is possible that through headwater capture (a tributary from one watershed joins with a tributary from another) there may have been natural migration of fish between the Pecos and Canadian headwater streams. Because there are Rio Grande cutthroat trout populations throughout the headwaters of the Rio Grande basin, historically, these fish most likely dispersed through the Rio Grande into the tributary streams.

There is some possibility that Rio Grande cutthroat trout may have occurred in the Pecos River basin in Texas (Behnke 1967, pp. 5, 6; Garrett and Matlock 1991, p. 404) and the Rio Grande basin in Mexico (Behnke 1967, p. 4). However, no specimens were collected to document their presence in these locations with certainty. Their potential occupancy in these locations is based on fluvial connections and on historical articles that describe the presence of trout that could have been Rio Grande cutthroat trout.

The range of the Rio Grande cutthroat trout has been divided by basins into five geographic management units (GMUs) to bring a greater resolution to descriptions of population and habitat distribution and related maintenance and restoration work (Figure 3). These GMUs reflect the hydrologic divisions of the Rio Grande cutthroat trout's historical range by river drainage. The GMUs are managed by the Conservation Team as separate units to maintain genetic and ecological diversity within the subspecies where it exists and to ensure representation of the subspecies across its historical range. However, the GMUs were not created to necessarily reflect important differences in genetic variability in the subspecies based on geography or adaptation to specific environments, although fish in the Pecos and Canadian GMUs do exhibit some genetic differentiation from those in the Rio Grande GMUs (Pritchard *et al*. 2009, p. 1216). Additionally, Rio Grande cutthroat trout are only known from one stream in the Caballo GMU – Las Animas Creek, where a hybridized population currently exists. No other historical locations are known within that GMU.

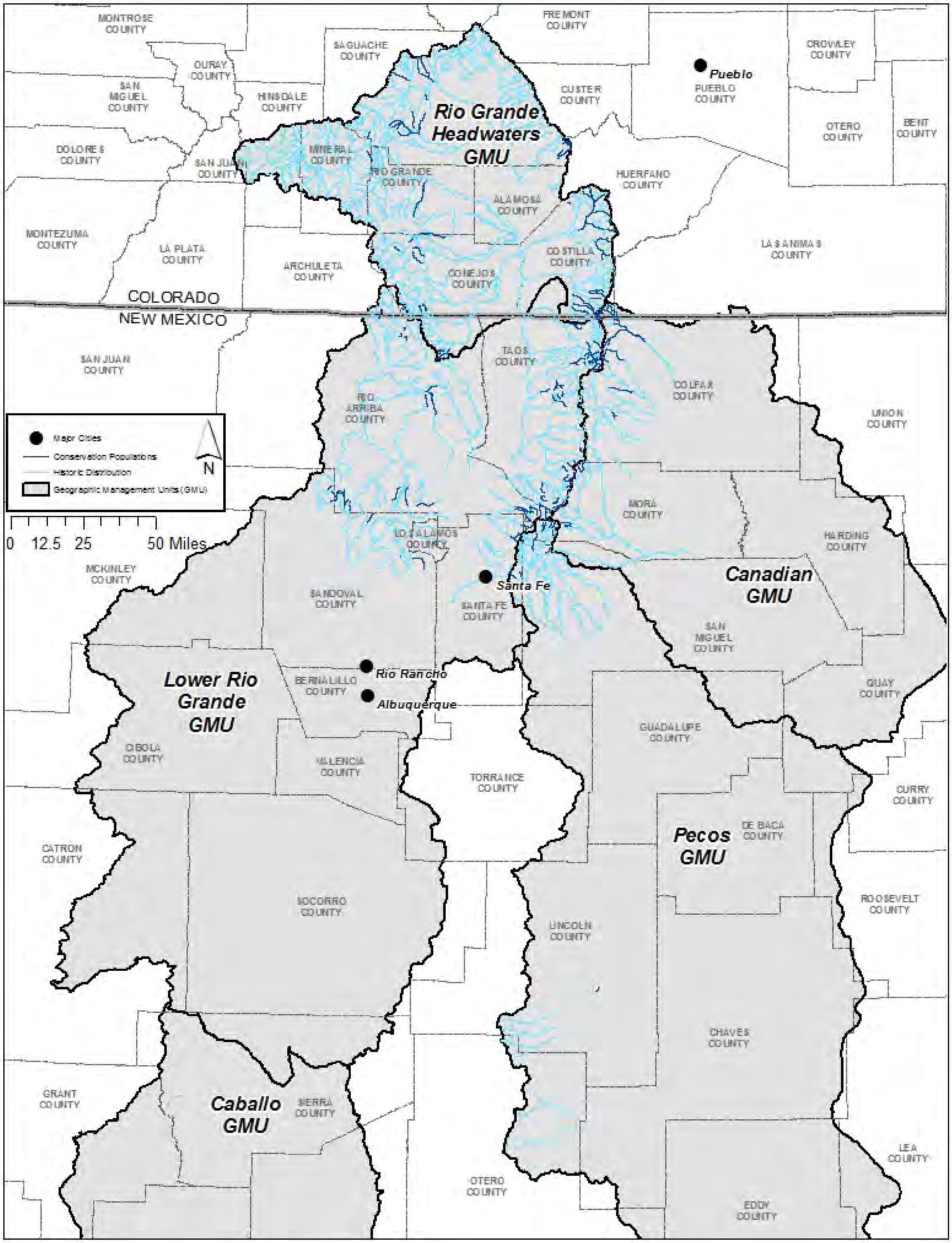


Figure 3. Presumed historical and current ranges of conservation populations of Rio Grande cutthroat trout. Light blue are presumed historically occupied streams, and dark blue streams are currently occupied streams. Map courtesy of New Mexico Department of Game and Fish and U.S. Fish and Wildlife Service.

3.2 Needs of the Rio Grande Cutthroat Trout

As discussed in Chapter 1, for the purpose of this assessment, we define **viability** as the ability of a species to persist over time and thus avoid extinction. Using the SSA framework, we describe the subspecies' viability by characterizing the status of the subspecies in terms of its **resiliency**, **redundancy**, and **representation** (the 3Rs). Using various time frames and the current and projected levels of the 3Rs we thereby describe the subspecies' level of viability over time. To measure these factors, we have created an analysis tool (see Appendix C, Rio Grande Cutthroat Trout Status Assessment Model, and Chapter 5, Viability) that forecasts the subspecies' condition in the future.

3.2.1 Population Resiliency

For the Rio Grande cutthroat trout to maintain viability, its populations, or some portion of its populations, must be resilient. To measure resiliency, we estimated the probability of persistence of each population over three time periods (see Chapter 5, Viability, and Appendix C, Species Status Assessment Model for more information). A number of factors influence the subspecies' viability, including population size and distribution, length of occupied habitat, the potential for nonnative fish invasions, and disease risk. Each of these factors is discussed here.

Resilient Rio Grande cutthroat trout populations must be of sufficient size to withstand demographic effects of low genetic diversity. Larger populations have a higher effective population size, which is a theoretical measure of the number of breeders in the population that contribute to genetic diversity. Populations with a low effective population size are more likely to experience genetic drift and inbreeding and are less likely to adapt to changing environmental conditions. General guidelines for trout have been developed that suggest effective population sizes of 500 and above have a low risk of genetic consequences and retain long term adaptive potential, and those below 50 are highly vulnerable to inbreeding depression and genetic drift (Allendorf *et al.* 1997, pp. 142–143; Rieman and Allendorf 2001, p. 756). Therefore, resilient populations have a sufficient effective population size to avoid adverse genetic consequences on the population.

Resilient Rio Grande cutthroat trout populations also occupy stream reaches long enough to provide the range of habitats needed to complete their life cycle (*i.e.*, spawning habitat, nursery habitat, adult habitat, refugial habitat) (Harig and Fausch 2002, p. 546; Young *et al*. 2005, p. 2406). The longer an unobstructed reach of stream, the more habitat variability is likely to be represented, which increases the likelihood of survival of various life stages (Young *et al.* 2005, p. 2406). In turn, higher likelihood of survival through the life stages supports a higher likelihood of successful recruitment (young individuals joining the breeding population) which supports a larger population size. Further, longer unobstructed stream lengths are more likely to provide habitat during periods of drought (when deep pools provide refugia), over winter (deep pools are less likely to freeze), and longer streams are more likely to provide sufficient complexity (tributaries, stream networking) to allow Rio Grande cutthroat trout populations to survive after stochastic disturbances such as debris flows following wildfire. Streams longer than about 9.65 km (6 miles) are generally assumed to be long enough to encompass the habitat complexity necessary for the population to survive stochastic events (Hilderbrand and Kershner

2000, p. 515; Cowley 2007, p. 9; Peterson *et al.* 2013, p. 10; Roberts *et al.* 2013, p. 12). Streams shorter than 2.8 km (1.7 miles) are unlikely to have enough habitat variability for a population to be able to survive stochastic events (Harig and Fausch 2002, pp. 538–539). Stream reaches smaller than 2.8 km may support populations of Rio Grande cutthroat trout, but local habitat quality is the greatest driver of population occurrence in short segments (Peterson *et al.* 2013, p. 10).

Additionally, resilient Rio Grande cutthroat trout populations are free from hybridization, competition, and predation by nonnative trout. Rainbow trout (*O. mykiss*) and nonnative cutthroat trout subspecies are known to readily hybridize with Rio Grande cutthroat trout (Pritchard and Cowley 2006, p. 3). Once Rio Grande cutthroat trout populations have more than 10% introgression (gene mixing) with nonnative species and subspecies, we no longer consider that population to be a conservation population (Rhymer and Simberloff 1996, pp. 83, 97); this level of introgression has been accepted by the larger cutthroat trout community (Utah Division of Wildlife Resources 2000, p. 4; Alves *et al.* 2008, p. 6). Therefore, resilient Rio Grande cutthroat trout populations must be free of nonnative hybridizing trout.

When brook (*Salvelinus fontinalis*) or brown (*Salmo trutta*) trout invade streams occupied by cutthroat trout, the native cutthroat trout decline over time or are displaced due to competition and predation (Harig *et al*. 2000, pp. 994, 998, 999; Dunham *et al*. 2002, p. 378; Peterson *et al.* 2004, p. 769; Paroz 2005, p. 34; Shemai *et al*. 2007, p. 323). While the use of piscicides (fish toxicants) is the most effective tool to completely eliminate nonnative species, piscicide use is not always feasible (Finlayson *et al.* 2005, pp. 10, 14). Nonnative suppression activities (*i.e.*, electrofishing and removing nonnative species), when occurring annually or nearly annually, can be effective at preventing the displacement of Rio Grande cutthroat trout by brook (Peterson *et al*. 2008b, p. 1861) or brown trout. Because of the high probability of population decline when Rio Grande cutthroat trout co-occur with brook or brown trout, resilient populations should either be free of nonnative trout or have suppression activities occurring regularly.

Finally, resilient Rio Grande cutthroat trout populations are free from disease. Whirling disease, in particular, poses a large risk to salmonid populations in Colorado and New Mexico; once infected, entire year classes are lost, and extirpation of the population is likely (Thompson *et al*. 1999, pp. 312–313). Therefore, resilient populations must be free of whirling disease.

3.2.2 Subspecies Redundancy and Representation

The Rio Grande cutthroat trout needs to have multiple resilient populations distributed throughout its historical range within the four GMUs[2] to provide for rangewide redundancy and representation. The wider the distribution of resilient populations and the larger the number of populations the more redundancy the subspecies will have. This redundancy reduces the risk that a large portion of the subspecies' range will be negatively affected by any catastrophic natural or anthropogenic event at any one time. Species that are well-distributed across their

[2] The Caballo GMU, having only one historical population, cannot have a wider distribution throughout that GMU. While that historical population is currently undergoing restoration (NMDGF *et al.* 2014, entire), if that restoration is unsuccessful it would only marginally affect the subspecies' redundancy and representation rangewide, as it constitutes such a small portion of the historical distribution.

historical range (*i.e.*, having high redundancy) are less susceptible to extinction and more likely to be viable than species confined to a small portion of their range (Carroll *et al*. 2012, entire; Redford *et al*. 2011, entire). From a rangewide perspective, multiple Rio Grande cutthroat trout populations should be dispersed throughout the four GMUs to provide for redundancy and subspecies' viability.

Maintaining representation in the form of genetic or ecological diversity is important to keep the capacity of the Rio Grande cutthroat trout to adapt to future environmental changes. Rio Grande cutthroat trout populations vary in the amount of genetic diversity they contain (Pritchard *et al.* 2007, p. 614; Pritchard *et al.* 2009, p. 1216). The Canadian and Pecos GMUs represent significant genetic differentiation from those in the Rio Grande Headwaters and Lower Rio Grande GMUs (Pritchard *et al.* 2009, p. 1219). The Rio Grande cutthroat trout needs to retain populations in the Canadian and Pecos GMUs to maintain the overall potential genetic and life history attributes that can buffer the subspecies' response to environmental changes over time (Moore *et al.* 2010, pp. 340–341; Schindler *et al.*2010, p. 612). Although the GMU boundaries were not generated to represent genetic differences, they encompass the historical range of the Rio Grande cutthroat trout and, therefore, provide a picture of representation of the genetic diversity among populations and the ecological diversity across the subspecies' range. The GMUs serve as a proxy for geographic variation that may represent natural variation in the subspecies' genetic diversity.

To measure representation and redundancy, we estimated the number of persisting populations by GMU for three time periods to provide a geographical estimate of where the Rio Grande cutthroat trout populations will persist into the future (see Chapter 5, Viability, and Appendix C, Species Status Assessment Model for more information).

3.2.3 Subspecies Current Conditions

The current conditions of the Rio Grande cutthroat trout can be summarized based on the number, status, and distribution of the current conservation populations. Conservation populations are those populations of Rio Grande cutthroat trout with less than 10% hybridization with nonnative trout. A single conservation population can include multiple reaches of a stream through which a population may move, or it may encompass only a single reach. As a snapshot of the current condition of the subspecies, we categorized the current 122 conservation populations into four categories (Table 2) based on four main factors affecting their current condition: effective population size, occupied stream length, presence of competing nonnative trout, and presence of hybridizing nonnative trout. Each population was placed in a category of current condition (Best, Good, Fair, and Poor) based on the combination of the four factors as defined in Table 3. For example, a population with an effective population size of 400, a stream length of 6 km, and no competing or hybridizing nonnatives would sort into the "Good" category. Additionally, all populations with hybridizing nonnative trout or effective population sizes of less than 50 would sort into the "Poor" category. Our discussion and analysis of these factors is found in Appendix C.

Table 2. Current status of Rio Grande cutthroat trout showing the number of current conservation populations in four categories by GMU. The percentages (%) are the proportion of total populations within each GMU.

Populations per GMU	Best	%	Good	%	Fair	%	Poor	%	Total
Canadian	1	10%	3	30%	5	50%	1	10%	10
Rio Grande Headwaters	5	12%	14	34%	20	49%	2	5%	41
Lower Rio Grande	13	22%	15	25%	20	34%	11	19%	59
Pecos	1	8%	3	25%	7	33%	1	42%	12
Rangewide	20	16%	35	29%	52	43%	15	12%	122

Overall, we found 20 populations across the range of the Rio Grande cutthroat trout that were in the "Best" condition—that is, they have a long occupied stream reach (>9.65 km), large effective population size (>500), and no nonnative trout present (see Table 3). We found 15 populations rangewide that were in "Poor" condition—that is, either hybridizing nonnative trout were present or the effective population size was less than 50 individuals. The remaining 35 and 52 populations sorted as "Good" and "Fair," respectively (Table 3).

Table 3. Definitions of four categories (Best, Good, Fair, Poor) used to represent the current condition of conservation populations of Rio Grande cutthroat trout. Each population was placed in a category based on the combination of metrics as indicated by the highlighted colors. See Appendix C for additional information on the factors used to assess the status of the Rio Grande cutthroat trout. A population is placed in a category by meeting any one set of conditions identified.

Categories	Sets of Conditions			
BEST CATEGORY	**Set 1**			
1. Effective Population Size	**>500** 500-201 200-50 <50			
2. Occupied Stream Length (KM)	**>= 9.65** **9.64-7.1** 7.09-2.8 <2.8			
3. Hybridizing Nonnative Trout Present	**No** Yes			
4. Competing Nonnative Trout Present	**No** Yes			
GOOD	**Set 1**	**Set 2**	**Set 3**	
1. Effective Population Size	**>500** 500-201 200-50 <50	**>500** 500-201 200-50 <50	>500 **500-201** 200-50 <50	
2. Occupied Stream Length (KM)	**>= 9.65** **9.64-7.1** 7.09-2.8 <2.8	>= 9.65 9.64-7.1 **7.09-2.8** <2.8	**>= 9.65** **9.64-7.1** **7.09-2.8** <2.8	
3. Hybridizing Nonnative Trout Present	**No** Yes	**No** Yes	**No** Yes	
4. Competing Nonnative Trout Present	No **Yes**	**No** Yes	**No** Yes	
FAIR	**Set 1**	**Set 2**	**Set 3**	**Set 4**
1. Effective Population Size	**>500** **500-201** 200-50 <50	>500 500-201 **200-50** <50	>500 **500-201** **200-50** <50	**>500** 500-201 200-50 <50
2. Occupied Stream Length (KM)	>= 9.65 9.64-7.1 7.09-2.8 **<2.8**	**>= 9.65** **9.64-7.1** **7.09-2.8** **<2.8**	**>= 9.65** **9.64-7.1** **7.09-2.8** **<2.8**	>= 9.65 9.64-7.1 **7.09-2.8** **<2.8**
3. Hybridizing Nonnative Trout Present	**No** Yes	**No** Yes	**No** Yes	**No** Yes
4. Competing Nonnative Trout Present	**No** Yes	**No** Yes	No **Yes**	No **Yes**
POOR	**Set 1**	**Set 2**		
1. Effective Population Size	**>500** **500-201** **200-50** **<50**	>500 500-201 200-50 **<50**		
2. Occupied Stream Length (KM)	**>= 9.65** **9.64-7.1** **7.09-2.8** **<2.8**	**>= 9.65** **9.64-7.1** **7.09-2.8** **<2.8**		
3. Hybridizing Nonnative Trout Present	No **Yes**	**No** Yes		
4. Competing Nonnative Trout Present	**No** **Yes**	**No** **Yes**		

Another way to view the current status of the subspecies and compare it to historical conditions is using total stream lengths occupied by Rio Grande cutthroat trout. Alves *et al.* (2008, p. 13) estimated the total occupied stream lengths historically based on assumed occupancy for streams that would have likely supported the subspecies, based on the likelihood of suitable habitat being available. Historically it is estimated that the subspecies occurred in about 10,696 stream km, and currently we estimate it occurs in about 1,149 stream km, or about 11% of its historical distribution, and throughout four of the GMUs.

Table 4. Historical and current estimated stream kilometers occupied by Rio Grande cutthroat trout. Historical estimate is from Alves *et al.* (2008, p. 13).

Geographic Management Unit	Historically Occupied (km)	Percent of Historical Total		Currently Occupied (km)	Percent of Current Total
Canadian	1024	9.6%		147	12.8%
Rio Grande Headwaters	5265	49.2%		494	43.0%
Lower Rio Grande	3389	31.7%		446	38.8%
Caballo	17	0.2%		0	0.0%
Pecos	1001	9.4%		62	5.4%
Rangewide Total	10,696	100.0%		1,149	100.0%

Chapter 4. Risk Factors

> **Note:** This chapter contains **summaries** of the risk factors. For further information, see the tables in **Appendix B. Appendix C** contains detailed information about their application to the future condition of the subspecies.

In this chapter we review the past, current, and future risk factors that are affecting what the Rio Grande cutthroat trout needs for long term viability. We analyzed these risk factors in detail using the tables in Appendix B in terms of causes and effects to the subspecies. These tables analyze the pathways by which each stressor affects the subspecies, and each of the causes is examined for its historical, current, and potential future effects on the viability of the Rio Grande cutthroat trout. Each risk factor will be briefly reviewed here; for further information, refer to the tables in Appendix B. The most important factors affecting the future condition of the Rio Grande cutthroat trout were carried forward and analyzed in our Status Assessment Model (see Appendix C).

4.1 Demographic Risk

Small population sizes are at greater risk from reduced genetic diversity, which decreases a population's ability to adapt to environmental changes. Estimating the effective population size (a theoretical measure of the number of breeders in the population that contribute to genetic diversity) of a population is one way to measure the risk of a population experiencing those negative genetic effects. Effective population size is generally lower than census population size due to unequal sex ratios, variable probability of reproductive success, and nonrandom mating (Baalsrud 2011, p. 1). General guidelines developed for trout suggest effective population sizes of 500 and above have a low risk of genetic consequences and retain long term adaptive potential, and those below 50 are highly vulnerable to inbreeding depression and genetic drift (Allendorf *et al.* 1997, pp. 142–143; Rieman and Allendorf 2001, p. 756). To our knowledge, no populations of native trout have been extirpated due to demographic risk alone; instead, it is a factor that can make the population more vulnerable to extirpation from other factors. See p. B-3 for more analysis of demographic risk.

4.2 Hybridizing Nonnative Trout

The introduction of nonnative trout species (including those that hybridize with Rio Grande cutthroat trout and those that compete with them) into Rio Grande cutthroat trout habitat accounts for the majority of the 89% range loss of the subspecies. Nonnative rainbow trout and other cutthroat trout subspecies have historically been introduced throughout the range of Rio Grande cutthroat trout for recreational angling, and they are known to readily hybridize with Rio Grande cutthroat trout (Alves *et al.* 2008, p. 15). Hybrids can have reduced fitness, and even when fitness is increased, hybridization may disrupt important long-term adaptations of native populations (Allendorf *et al*. 2004, p. 1203). The genetic distinctiveness of Rio Grande cutthroat trout can be lost through hybridization (Allendorf *et al*. 2004, p. 1205), and once Rio Grande cutthroat trout populations have more than 10% introgression (gene mixing) with nonnative species and subspecies, that population is no longer considered a conservation population (Rhymer and Simberloff 1996, pp. 83, 97; Utah Division of Wildlife Resources 2000, p. 4).

Populations are not immediately affected after nonnative trout are introduced; it can take years (or decades) for Rio Grande cutthroat trout to be affected at the population level. In some cases it can take even longer for the genetic mixing from hybridization to exceed 10% introgression and for the population to no longer be considered a conservation population and, therefore, extirpated. Fisheries managers throughout the range of Rio Grande cutthroat trout have worked to eradicate nonnative trout from stream reaches historically occupied by Rio Grande cutthroat trout. In general, all hybridizing nonnative trout must be completely removed from the stream system in order to prevent hybridization from occurring. The eradication of nonnative trout includes removing all fish from the reach through the use of piscicides, installing fish passage barriers in streams to prevent future invasion by nonnative trout, and repatriating those reaches with pure Rio Grande cutthroat trout. Currently, 72 conservation populations (of 122; 59%) are protected by complete barriers to upstream fish movement and 14 conservation populations (of 122; 11%) are protected by partial barriers to upstream fish movement (RGCT Database). These barriers reduce the risk of future invasions by hybridizing, nonnative trout.

Rio Grande cutthroat trout continue to be vulnerable to the negative effects of hybridization with nonnative rainbow and Yellowstone cutthroat trout. We expect that accidental or intentional illegal introductions of rainbow trout may continue to occur, though infrequently, so nonnative trout will continue to pose some risk to Rio Grande cutthroat trout populations in the future. Once an invasion occurs, sympatry (co-occurrence) with nonnative hybridizing trout is a high risk to Rio Grande cutthroat trout population persistence. See p. B-6 for more analysis of nonnative hybridizing trout.

4.3 Competing Nonnative Trout

Other species of nonnative trout have historically been stocked throughout the range of the Rio Grande cutthroat trout, as well. Brook and brown trout compete with Rio Grande cutthroat trout for food and space, and larger adults are likely to predate upon young Rio Grande cutthroat trout (Dunham *et al.* 2002, p. 378; Fausch *et al*. 2006, pp. 9–10)[3]. While no stocking of brook or brown trout is currently ongoing in New Mexico or Colorado, both species are found throughout historical Rio Grande cutthroat trout waters. Water temperature, fine sediment, and the abundance of pools and woody debris influence the degree of brook and brown trout invasion (Shepard 2004, p. 1096). Currently, approximately 41% of Rio Grande cutthroat trout conservation populations (50 of 122) are known to co-occur with brook or brown trout. In general, over time native cutthroat trout populations will diminish and may become extirpated when they co-occur with brook and brown trout (Peterson and Fausch 2003, p. 769). As with the introduction of rainbow trout into a conservation population, Rio Grande cutthroat trout populations are not immediately affected after brook or brown trout are introduced; it can take many years for populations to decline and then become extirpated. Unlike with hybridizing trout species, managers can implement mechanical suppression (catching and removing nonnative trout species on a regular basis) within streams where Rio Grande cutthroat trout populations are sympatric with brook and brown trout in areas where complete eradication using piscicides is not feasible. However, eradication of all fish and repatriation with Rio Grande cutthroat trout

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[3] Throughout this SSA Report, we refer to brook and brown trout as "competing nonnative trout." We recognize that predation is also a stressor when these species co-occur with Rio Grande cutthroat trout, and this stressor is included in our analysis.

remains the most effective method of decreasing the risk of extirpation due to sympatry with nonnative competing trout species. Currently, 86 conservation populations are protected by complete or partial barriers to upstream fish movement (RGCT Database), reducing the risk of competing nonnative species invasions.

Rio Grande cutthroat trout continue to face pressure from competition with nonnative brook and brown trout. We expect that, as infrequent accidental and/or intentional illegal introductions occur (Johnson *et al.* 2009, p. 389), nonnative trout will continue to pose a risk to Rio Grande cutthroat trout populations in the future. See p. B-9 for more analysis of competing nonnative trout.

4.4 Wildfire

Wildfires are a natural disturbance in forested watersheds, particularly in the Southwest. However, since the mid-1980s, wildfire frequency in western forests has nearly quadrupled compared to the average frequency during the period 1970 – 1986 (Westerling *et al.* 2006, p. 941), and this increase is widely attributed to climate change (McKenzie *et al.* 2004, p. 893; Westerling *et al.* 2006, p. 942; IPCC 2007a, p. 15). Risk of wildfires can be affected by forest management activities; fire suppression or a lack of thinning or prescribed burns can enhance conditions suitable for high-intensity wildfires (Schoennagel *et al*. 2004, p. 669). Although Rio Grande cutthroat trout may survive after a fire burns through a watershed, ash and debris flows that occur after a fire can eliminate populations of fish from a stream (Rinne 1996, p. 654; Brown *et al*. 2001, p. 142). In the past, this was likely not a significant factor affecting Rio Grande cutthroat trout, as interconnected populations provided a source for repatriation of extirpated areas. However, the fragmentation experienced by most Rio Grande cutthroat trout populations prevents recolonization after extirpation. Wildfires within the range of Rio Grande cutthroat trout have depressed or eliminated fish populations (Japhet *et al*. 2007, p. 20; Patten *et al.* 2007, pp. 33, 36; RGCT Database). The amount of ash flow from a fire depends on the severity of the fire, proximity to the stream habitat, stream channel morphology, timing, and amount of rainfall following the fire (Rinne 1996, p. 656; Rieman and Clayton 1997, p. 9).

The extent of one or more populations being affected by wildfire depends on the location of the fire, the length and amount of stream networking of the occupied stream reach, and the extent of stream networking (Roberts *et al*. 2013, p. 6). For example, Polvadera Creek, in the Lower Rio Grande GMU, burned during the South Fork Fire in 2010, and ash flows following that fire nearly eliminated the subspecies from the stream. However, during subsequent fish surveys, young-of-year Rio Grande cutthroat trout were found in the headwaters of the stream (RGCT Database), indicating suitable habitat remained and the population survived in low numbers. The presence of stream reaches that provide refugia during and after fires plays a large role in the ability of the population to repatriate affected areas (Rieman and Clayton 1997, p. 10).

Wildfires may also provide opportunities for Rio Grande cutthroat trout restoration. Just as ash and debris flows following wildfires can eliminate Rio Grande cutthroat trout populations, they can also eliminate nonnative trout. Once the stream has been confirmed to be fishless, and the habitat has regained stability, Rio Grande cutthroat trout can be repatriated to the affected stream reach. This situation has occurred in Pinelodge Creek (Pecos GMU) and Capulin Creek (Lower

Rio Grande GMU) in the past with successful re-establishment of Rio Grande cutthroat trout (NMDGF 2013, p. 3). The recent Las Conchas Fire in New Mexico (Lower Rio Grande GMU) has resulted in the elimination of nonnative trout from 5 stream reaches that NMDGF is planning to restock with Rio Grande cutthroat trout (NMDGF 2013, p. 3).

As drought frequency increases due to climate change, dry forests are more likely to burn and burn hotter than they have in the past (Glick 2006, p. 8). Wildfire risk analysis rangewide (Miller and Bassett 2013, entire) shows that if a wildfire is ignited, all of the watersheds supporting Rio Grande cutthroat trout populations have a high risk of burning and of resulting in high levels of debris flow. The only exceptions are for some populations in the Rio Grande Headwaters GMU, which have a moderate risk of fire and debris flow. This risk analysis evaluated the potential behavior of a fire if it started, based on flame length and crown fire potential. Fuels management may be done on a local scale to reduce some risks; however, given that climate change will increase the likelihood of large, hot fires throughout the Southwest, we expect that the effects of wildfire will continue to result in loss of Rio Grande cutthroat trout populations in the future. See p. B-13 for more analysis of wildfire.

4.5 Stream Drying

Stream drying within Rio Grande cutthroat trout populations may occur as a result of drought or, in a few cases, water withdrawals. As streams begin to dry, the amount of habitat available for Rio Grande cutthroat trout is reduced; streams may become more narrow and intermittent. Drought frequency is expected to increase as a result of climate change due to a combination of increased summer temperatures and decreased precipitation (Nash and Gleick 1993, p. ix; IPCC 2007a, p. 15; Ray *et al.* 2008, p. 37; Haak and Williams 2012, p. 388). Stream intermittency may cause water quality declines (increased temperature, decreased oxygen), lack of access to breeding, feeding, and sheltering areas, and stranding of fish (Lake 2000, p. 577). In the past, this was likely not a significant factor affecting Rio Grande cutthroat trout, as interconnected populations provided a source for repatriation of extirpated areas. However, the fragmentation experienced by most Rio Grande cutthroat trout populations prevents recolonization after extirpation, in most cases. Streams with drought refugia (pools or other areas that remain wetted during dry times) within the occupied reaches can increase the chances of populations surviving if stream drying occurs.

Climate change is expected to increase the frequency and severity of drought, which will result in streams continuing to become intermittent and risking loss of Rio Grande cutthroat trout populations. Reduced summer streamflows have already been observed throughout the range of Rio Grande cutthroat trout (Zeigler *et al.* 2012, p. 1050), and population extirpations have been observed in a few cases (Japhet *et al.* 2007, pp. 42–45; J. Alves, CPW, 2014 pers. comm.). We expect that stream drying as a result of drought and, in some cases, water withdrawals will continue to result in population effects and risk of extirpations throughout the subspecies' range. See p. B-17 for more analysis of stream drying.

4.6 Disease

Whirling disease is caused by a nonnative parasite (*Myxobolus cerebralis*), which requires two separate hosts to complete its life cycle: a salmonid fish and an aquatic worm (*Tubifex tubifex*). Spores of the parasite are released when infected fish die; these spores are ingested by the *T. tubifex* worm, where they undergo transformation in the gut to produce actinosporean triactionomyxons (TAMs). Trout are infected either by eating the worms (and TAMs) or through contact with TAMs after they have been released from the worms into the water. The myxosporean parasite became widely distributed in Colorado in the early 1990s through the stocking of millions of catchable size trout from infected hatcheries (Nehring 2007, p. 1). Parasites damage cartilage, killing young fish or causing infected fish to swim in an uncontrolled whirling motion, making it impossible to avoid predation or feed (Hiner and Moffett 2001, p. 130). Mortality rates of 85% or more may occur within 4 months of exposure (Thompson *et al.* 1999, p. 312). Once *M. cerebralis* is present, total year class failure of Rio Grande cutthroat trout can occur (Nehring 2008, p. 2), and precipitous population declines may result (Thompson *et al.* 1999, p. 313).

NMDGF policies and regulations prohibit the stocking of any whirling disease positive fish in the State of New Mexico (Patten and Sloane 2007, p. 10). In Colorado, stocking of whirling disease-positive fish in protected habitats, which include native cutthroat trout waters, is prohibited (Japhet *et al*. 2007, p. 12).

We expect Rio Grande cutthroat trout populations will occasionally become infected with whirling disease in the future. Risk of disease is gauged by the distance of the population to known locations of whirling disease. No conservation populations are currently determined to be infected or at high risk of infection, and only 7% of conservation populations (9 of 122) have been determined to be at moderate risk of whirling disease infection (i.e., they are within 10 km (6.2 mi) of known whirling disease locations) (Alves *et al.* 2008, p. 38). Because fish movement barriers help guard populations again infection by preventing the invasion of infected trout, and whirling disease has affected very few Rio Grande cutthroat trout populations to date, whirling disease poses extremely low risks to the majority of Rio Grande cutthroat trout populations because of the low likelihood of infection. See p. B-21 for more analysis of disease.

4.7 Water Temperature Changes

Stream warming due to climate change has been observed throughout salmonid habitat in the west, and summer high water temperatures may become a key bottleneck for many species of trout (Isaak *et al.* 2012a, p. 514). Stream warming trends induced by climate change can cause some streams to become too warm for Rio Grande cutthroat trout populations to thrive, while several streams that are currently colder than optimal will warm and become more suitable (Zeigler *et al*. 2013a, p. 1400; Zeigler *et al.* 2013b, pp. 6–9). Air temperatures in the last 45 years throughout the range of Rio Grande cutthroat trout have increased an average of 0.29 °C (0.5 °F) per decade (Zeigler *et al*. 2012, p. 1049). The extent to which streams will warm varies with elevation, slope, and aspect.

As with Colorado River cutthroat trout (*O. c. pleuriticus*) (Roberts *et al.* 2013, p. 13), Rio Grande cutthroat trout populations are currently restricted to higher elevations due to nonnative trout interactions, and the effects of warming temperatures do not appear to be as stark as previously thought. No populations throughout the range of Rio Grande cutthroat trout are currently experiencing acute effects (mortality) due to high temperature; and one population may be experiencing chronic effects (such as reduced growth) due to current stream temperatures (Rogers 2013, pp. 18–21; Zeigler *et al.* 2013a, p. 1400; Zeigler *et al.* 2013b, pp. 6–9). In the future, climate change may cause summer water temperatures to increase, potentially putting future populations at risk from chronic and acute temperature effects. We found that the majority of the high elevation headwater streams where Rio Grande cutthroat trout are currently found are not expected to experience significant temperature increases; therefore, most Rio Grande cutthroat trout populations have an extremely low risk of extirpation over the next 65 years due to water temperature increases. See p. B-23 for more analysis of water temperature changes.

4.8 Changes in Flood Timing and Magnitude

Changes in precipitation and air temperature expected from climate change (becoming drier and warmer) will likely lead to changes in the magnitude, frequency, timing, and duration of spring snowmelt runoff patterns, as well as water temperature changes in streams occupied by Rio Grande cutthroat trout (Poff *et al.* 2002, p. 4; Isaak *et al.* 2012b, p. 544). The life history of salmonids is closely tied to flow regime, runoff in particular (Fausch *et al*. 2001, p. 1440). An increase in magnitude of floods (perhaps due to rain on snow events) can scour streambeds, destroy eggs, or displace recently emerged fry downstream (Erman *et al*. 1988, p. 2199; Montgomery *et al*. 1999, p. 384). Climate warming is also causing snowmelt runoff to peak approximately 10 days earlier in the spring than 45 years ago (Clow 2010, p. 2297; Zeigler *et al.* 2012, p. 1050). The environmental cues for Rio Grande cutthroat trout spawning are most likely tied to increasing water temperature, increasing day length, and possibly flow, as it has been noted that they spawn when runoff from snowmelt has peaked and is beginning to decrease (Behnke 2002, p. 141; Pritchard and Cowley 2006, p. 25). Earlier runoff could disrupt spawning cues because peak flow would occur when the days are shorter in length and, therefore, water temperatures are colder (Stewart *et al*. 2005, p. 1137). This earlier snowmelt, which leads to less flow in the spring and summer, could either benefit Rio Grande cutthroat trout or be detrimental. The benefit could come because the young-of-year would have a longer growing season before winter. However, as discussed above, a longer season of lower flows would lead to increased stream temperatures and increased probability of intermittency and drying.

In summary, it is difficult to project how changes in the hydrograph as a result of climate change will affect Rio Grande cutthroat trout populations. If the growing season is increased because of changes in flood timing and magnitude, they could be beneficial to Rio Grande cutthroat trout by increasing recruitment rates thanks to a longer summer growing season. However, if spawning cues are disrupted or egg and fry survival is reduced because of large magnitude floods during spawning or rearing times, it would negatively affect populations. However, because the large uncertainty regarding the extent and effects of these hydrological changes on Rio Grande cutthroat trout populations makes it difficult to draw reasonably reliable conclusions, and because the effects of hydrological changes that may result in stream drying are captured in the

Stream Drying discussion (see section 4.5, above), the effects of hydrological changes are not carried forward as an analyzed risk in the Status Assessment Model (Appendix C). See p. B-25 for more on changes in flood timing and magnitude.

4.9 Land Management

Cattle grazing, timber harvest, non-angling recreation, road building, and mining all occur within watersheds occupied by Rio Grande cutthroat trout, and all of these activities may lead to stressors that can affect the subspecies. While each activity can reduce riparian vegetation (eliminating cover and potentially resulting in water temperature increases), increase sedimentation (reducing instream habitat quality), increase erosion (reducing stream stability and cover), reduce food availability (overgrazing results in a reduction of terrestrial insects, which generally represent about half the diet of trout) (Saunders and Fausch 2007, p. 1224; 2012, p. 1525), and negatively affect habitat occupied by Rio Grande cutthroat trout, these practices have decreased in severity in recent decades (USFS 2005 (70 FR 68264); Poff *et al.* 2011, p. 2). Some land management activities are occurring throughout the range of the subspecies. Locally, land management activities may still be having some effects on aquatic habitat resulting in limited effects on Rio Grande cutthroat trout. However, the intensity of grazing and other activities is generally light because most of the streams Rio Grande cutthroat trout populations currently occupy are in high elevation, remote areas. We do not expect this to change in the future, given the ruggedness of the landscape and that the land management agencies are party to the Conservation Agreement and Strategy. Therefore, we do not think that land management activities will have measureable population-level effects in the future. See p. B-27 for more analysis of land management.

4.10 Angling

Recreational angling occurs on approximately 84% of Rio Grande cutthroat trout conservation populations (Alves *et al.* 2008, p. 47). Fishing regulations in New Mexico and Colorado appropriately manage recreational angling. For example, many of the streams with Rio Grande cutthroat trout are “catch and release.” Those that are not have a 2 (New Mexico) or 4 (Colorado) fish limit. While even catch and release angling can have some effects on individual fish (*i.e.*, handling stress, swallowing hooks) (Bartholomew and Bohnsack 2005, p. 140), many conservation populations of Rio Grande cutthroat trout are in very remote areas and angling pressure is light (Alves *et al.* 2008, p. 47). For these reasons, we do not expect angling is affecting or will affect Rio Grande cutthroat trout populations in the future. See p. B-31 for more analysis of angling.

4.11 Management Actions

The Rio Grande Cutthroat Trout Rangewide Conservation Team developed the Conservation Agreement and Strategy in 2013 (revised from the previous Conservation Agreements in 2003 and 2009). The Conservation Strategy formalized many of the management actions that have been ongoing for the subspecies for decades. Activities such as stream restorations, barrier construction and maintenance, nonnative species removals, habitat improvements, public outreach, database management, and many other activities are described in detail. Over the 10-

year life of the Agreement and Strategy, the Conservation Team has committed to restoration of between 11 and 20 new Rio Grande cutthroat trout populations to historical habitat. If the Agreement and Strategy are implemented as planned, the result would be at least 11 new highly resilient Rio Grande cutthroat trout conservation populations throughout the range of the subspecies. Because of the history of active management of this subspecies by the states of Colorado and New Mexico as well as land management agencies, we expect that even in the absence of the Agreement and Strategy beyond the time period of the current agreement, many management activities would continue to occur. Therefore, for projections after 2023, we analyzed the viability of the subspecies under varying management scenarios. Refer to Appendix C for additional details. See p. B-33 for more analysis of management actions.

4.12 Climate Change

Climate change has already begun, and continued greenhouse gas emissions at or above current rates will cause further warming (IPCC 2007a, p. 13). Warming in the Southwest is expected to be greatest in the summer (IPCC 2007b, p. 887), and annual mean precipitation, length of the snow season, and snow depth are very likely to decrease in the Southwest (IPCC 2007b, p. 887; Ray *et al.* 2008, p. 1). Effects of climate change, such as air temperature increases, drought, and timing and magnitude of flood flows, have been shown to be occurring throughout the range of Rio Grande cutthroat trout (Zeigler *et al*. 2012, pp. 1051–1052), and these effects are expected to exacerbate several of the stressors discussed above, such as water temperature, stream drying, and wildfire (Wuebbles *et al.* 2013, p. 16). We also considered changes in hydrological patterns, although due to the uncertainty in the extent and effects on populations, we did not carry that risk factor forward in our model. In our analysis of the future condition of the Rio Grande cutthroat trout, we added an assessment of how climate change is likely to exacerbate the stressors of hybridizing nonnative trout, stream temperature, stream drying, and the effects of wildfire (see Appendix C for detailed information of how this was assessed).

4.13 Synthesis

Our analysis of the past, current, and future factors that are affecting what the Rio Grande cutthroat trout needs for long term viability revealed that seven of these factors are having the largest influence on future viability of the subspecies. These factors are demographic risk, nonnative hybridizing trout, nonnative competing trout, wildfire risk, stream drying risk, water temperature risk, and disease risk. Other factors, such as land management, recreational angling, and hydrological changes, may be having local effects on populations but do not appear to be affecting the subspecies at a population scale. Therefore, our Status Assessment Model (Appendix C) included these seven factors when examining risks to Rio Grande cutthroat trout populations.

Chapter 5. Viability

We have considered what the Rio Grande cutthroat trout needs for viability and the current condition of those needs (Chapters 2 and 3), and we reviewed the risk factors that are driving the historical, current, and future conditions of the species (Chapter 4 and Appendix B). We now consider what the subspecies' future conditions are likely to be. We analyzed the future conditions based on a Status Assessment Model that allowed us to quantitatively forecast the future status of the subspecies based on our understanding of the risks faced by the Rio Grande cutthroat trout. We apply the results of our model to the concepts of resiliency, redundancy, and representation to describe the viability of the Rio Grande cutthroat trout.

> **Note:** This chapter contains **summaries** of the analysis of viability. For further information, see **Appendix C** which contains detailed information about how we modeled the future conditions of the subspecies.

5.1 Introduction

The Rio Grande cutthroat trout has undergone a precipitous decline in overall distribution and abundance, as is evidenced by the currently occupied stream habitat being on the order of 11% of the presumed historical range. The resulting remnant populations are small compared to presumed historical populations, and, for the most part, they are isolated from other populations in high elevation, headwater streams. The primary reason for this reduction in range and abundance was the introduction of nonnative trout species. Rainbow trout and other subspecies of cutthroat trout had the most obvious impact by hybridizing with Rio Grande cutthroat trout, and, secondarily, brown trout and brook trout also impacted the native trout through competition and predation.

While the future impacts from nonnative species are still a concern to the extant populations, the risk of additional introductions has been largely curtailed due to aggressive and sustained management actions by State management agencies and Federal, Tribal, and private land managers. The main management activities used to reduce the risk of future nonnative invasions are: 1) the cessation of stocking additional nonnative trout in waters near extant Rio Grande cutthroat trout conservation populations, 2) conversion to only stocking triploid rainbow trout (trout possessing three sets of chromosomes instead of two, and are therefore unable to reproduce) in New Mexico waters in Rio Grande cutthroat trout watersheds, 3) the removal of nonnative trout from occupied habitat, and 4) the construction and maintenance of fish barriers in streams that reduce the chance of future invasions of nonnative trout through dispersal to upstream Rio Grande cutthroat trout populations.

Because the remaining populations of Rio Grande cutthroat trout are generally small (compared to historical populations) and isolated, they are likely less resilient than in the past. Now a single stochastic event such as wildfire, and subsequent ash-laden floods, could eliminate an entire population of Rio Grande cutthroat trout. The impacts at the subspecies level are heightened by the isolated nature of the populations because natural recolonization of lost stream segments, which may have been likely historically, now are no longer possible because nearby or connected populations do not exist in most cases. We expect that the frequency and intensity of wildfire is likely to only become greater as the landscape gets warmer and drier from ongoing climate change.

Another source of stress to Rio Grande cutthroat trout, which may not have been significant historically because of the broad distribution of the subspecies, is the loss of populations due to stream drying. Obviously as stream flows decline due to anthropogenic factors of water use (either surface or groundwater), or due to drought, which may be heightened by climate change, then populations can be lost. Therefore, because populations are isolated, lost populations cannot be naturally recolonized.

In addition to those factors that have affected the subspecies in the past (such as wildfire and stream drying), there are several relatively new factors affecting the subspecies. Whirling disease was introduced in the 1990s, and when a population is infected it generally cannot recover. Additionally, climate change is expected to result in warmer stream temperatures, potentially further restricting the range of the subspecies.

Any of these stressors, alone or in combination, could result in the extirpation of populations which would decrease the overall redundancy and representation of the subspecies. Historically the subspecies, with a large range of interconnected populations, would have been resilient to stochastic events such as drought and wildfire because even if some populations were extirpated by such events, they could be recolonized over time by dispersal from nearby surviving populations. This connectivity would have made for a highly resilient subspecies overall. However, under current conditions, restoring that connectivity on a large scale is not feasible due to the wide-ranging presence of nonnative trout species. In fact, rather than increasing stream connectivity, in most locations managers are maintaining fish barriers to keep out nonnative trout rather than building connectivity (see exception on Vermejo Park Ranch, where nearly 161 stream km (100 stream miles) are being restored and reconnected (Vermejo Park Ranch *et al.* 2013, entire)).

As a consequence of these current conditions, the viability of the subspecies now primarily depends on maintaining as many as possible of the remaining isolated populations and restoring new populations where feasible. Management actions to expand existing populations where possible, to remove nonnative trout from occupied habitat, to maintain nonnative fish barriers where needed, and to restore new populations of Rio Grande cutthroat trout are now imperative to the long-term viability of the subspecies. The resiliency of the subspecies has been reduced at the subspecies level, but how is this reduction affecting the overall viability of the subspecies as we consider the future status of the Rio Grande cutthroat trout? We developed a Status Assessment Model to help address this question.

5.2 Forecasting Future Conditions

5.2.1 Status Assessment Model

We undertook an analysis (Appendix C) to quantitatively forecast what the future condition of the Rio Grande cutthroat trout in a way that characterizes viability in terms of the subspecies' resiliency, redundancy, and representation (Figure 4). The purpose of this analysis was to quantitatively reflect our understanding of the future viability of this subspecies by explicitly considering all the factors we found to be potentially affecting population persistence and by using our professional judgment to apply the best available information to assess the status of the Rio Grande cutthroat trout. Our objectives were twofold: 1) to estimate the probability of persistence of each extant Rio Grande cutthroat trout population over time; and 2) describe the future persistence of Rio Grande cutthroat trout by forecasting the likely number of populations expected to persist across the subspecies' range over time. As a consequence we developed two separate, but related, modules that:

1. Estimate the probability of persistence for each Rio Grande trout population by GMU for 3 time periods under a range of conditions; and
2. Estimate the number of surviving[4] populations by GMU for 3 time periods under several scenarios.

For the first module, we used seven risk factors to estimate the probability of persistence of each Rio Grande cutthroat trout population (Figure 4). For each risk factor, we used one or more population metrics that contribute to the risk of extirpation of the populations. We used our expert judgment to develop risk functions for each population metric. These judgments were based on our understanding of these risk factors as explained in Appendix B and Chapter 4. We only considered the risk factors that we deemed are likely to have population level impacts based on analysis of the causes and effects of those risk factors (Chapter 4 and Appendix B). For four of the risk factors, we accelerated the rate of risk increase over time because we believe that environmental changes associated with global climate change will likely increase the risks associated with those factors (see Appendix C, p. C-8 for more discussion of the risk associated with climate change). We summed all the risk functions for each population and subtracted that sum from 1 to calculate a probability of persistence for each population. We did this calculation for each population for future timeframes of 2023, 2040, and 2080. We also calculated the probability of persistence with and without suppression management activities for controlling competing nonnative trout for the 10 populations where suppression is currently occurring. And we did the analysis under two climate change conditions with moderate and severe effects of climate change. These forecasts resulted in a description of the resiliency of the populations in terms of probability of persistence of the current populations. By analyzing the resulting persistence probabilities by GMU, the results also provide a picture of representation and redundancy.

For the second module, we conducted a survival simulation based on the output of persistence probabilities from module 1 to forecast the number of populations that may survive over time (Figure 4). To do this, we used a randomization process to simulate whether a population remains extant or goes extinct based on our modeled probability of persistence. The simulation compares a random number (simulating a possible extirpation event), drawn from a uniform distribution between 0 and 1, to the estimated probability of persistence. If the random number is greater than the probability of persistence, for that iteration that population gets a 0 and is extirpated. If the random number is less than the probability of persistence, for that iteration,

[4] For this report, the terms "persisting" and "surviving" are used interchangeably when referring to populations sustaining themselves beyond the end points evaluated.

that population gets a 1 and survives. We summed the number of extant populations for each replication, and, after running the simulation 100 times, we calculated a mean number of surviving populations by GMU with a 95% confidence interval. We then added to those simulated number of surviving populations an estimate of the number of populations that may be restored over time by proactive management. Forecasting future restoration efforts has a large amount of uncertainty beyond the next 10 years, so we used a range of possibilities to include in the model output. For the overall population survival model, we considered 9 possible scenarios including the 3 time intervals that produce a best case, worse case, and intermediate case. The scenarios represent different combinations of assumptions based on: 1) level of climate change effects (moderate or severe); 2) whether or not suppression of nonnatives occurs; 3) the output of the population simulation model (mean and $\pm$ 95 % confidence interval); and 4) the projected level of future population restorations (low, mid, or high). The results from this analysis provides an assessment of future redundancy and representation based on the number of forecasted surviving populations rangewide and an assessment of representation as we report the results by GMU over time.

We also estimated the potential number of stream kilometers that are forecasted to be occupied in the future using our future population simulation. We did this in order to compare the current and future status of the Rio Grande cutthroat trout to the historical status in terms of total amount of occupied habitat. This estimation is not very precise, however, because we had to make large assumptions in estimating the future amount of occupied stream kilometers by population. Therefore, we only use these results as a general guide to compare the possible total occupied habitat in the future to what was present historically and currently.

For a detailed description of the methodology used in this analysis, as well as a discussion of the strengths and limitations of this analysis, please refer to Appendix C, Rio Grande Cutthroat Trout Status Assessment Model.

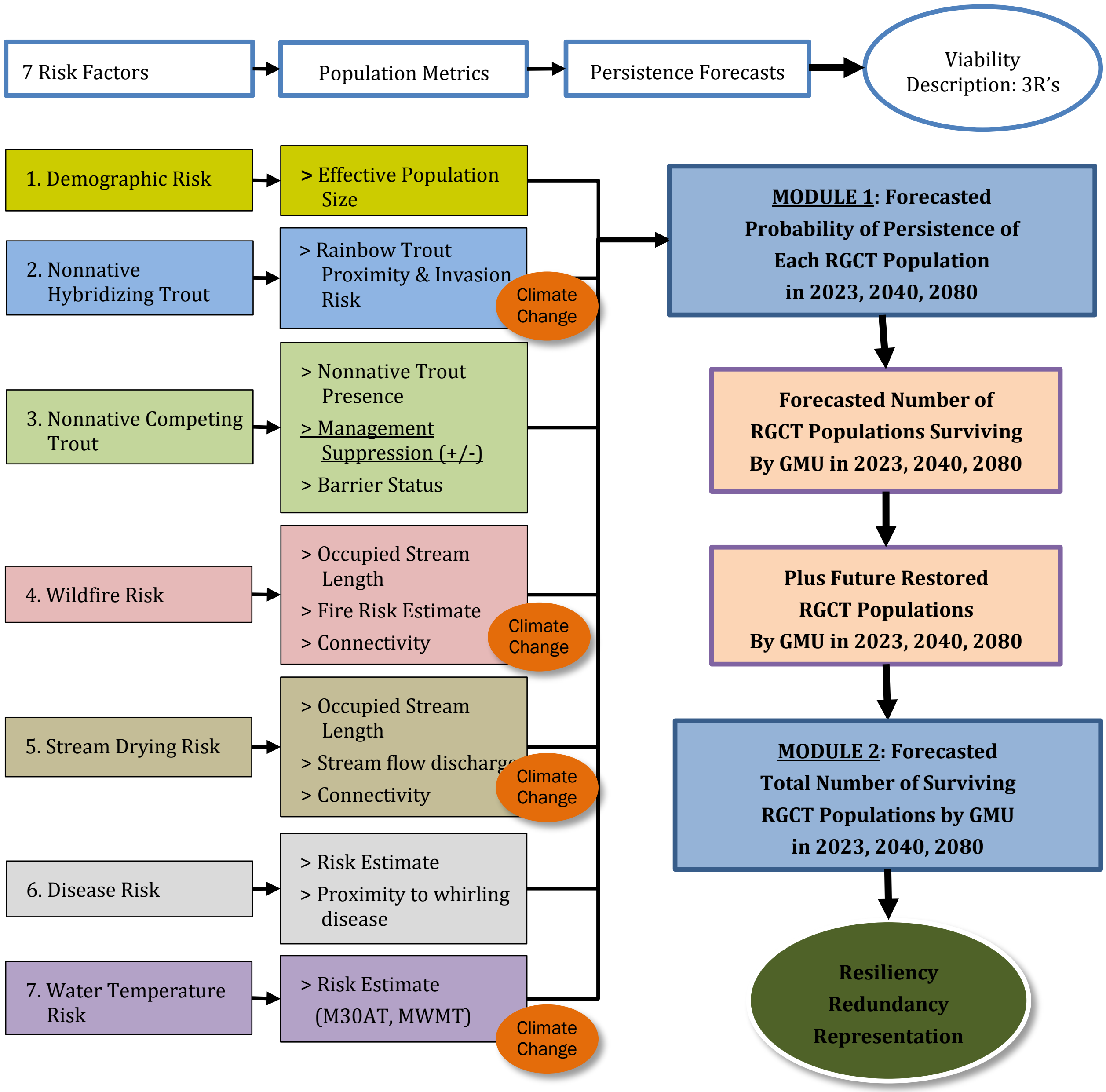

Figure 4. Conceptual diagram of Rio Grande cutthroat trout status assessment model.

5.3 Results: Module 1, Probability of Persistence

An overview of the resulting probability of persistence (on a scale from 0 to 1) for each population is shown in Figures 5 and 6. These scatter plots display 6 of the possible 10 conditions (see Appendix C, Figure C2 for each condition analyzed), but they demonstrate the range of results for each population.

For Figure 7 (and following Figures 8, 10, 12, and 14) we display the results of the population persistence analysis as frequency histograms, similar to Roberts *et al.* (2013, p. 1393). These figures display the probability of persistence over time under various conditions. For 2023, we analyzed the conditions with and without suppression activities and no climate change effects. For the 2040 and 2080 time periods, we show the results with no management suppression and with moderate and severe climate change effects. For these results, we used persistence probability categories of high (greater than 0.9), mod (moderate between 0.75 and 0.9), low (0.5 to 0.75) and minimal (less than 0.5). Figures 8, 10, 12, and 14 also show frequency distributions for the same conditions for each of the four GMUs. Figures 9, 11, 13, and 15 geographically show the location of the populations with the persistence probabilities for 3 sets of conditions over the 3 timeframes. For the 2023 maps we used the condition with nonnative trout suppression. For the 2040 and 2080 maps we used the condition without nonnative trout suppression and with moderate climate change effects.

Although management by the States of Colorado and New Mexico is likely to continue in the future beyond 2023, we are unable to predict when or where the efforts may occur that far into the future. Therefore, to show a conservative estimate of the probability of persistence of the populations in 2040 and 2080, we did not include in these results the nonnative suppression efforts on the streams that are currently being suppressed. Those conservation efforts currently affect the results of 10 of the 122 populations analyzed; therefore, it would not make a substantial difference in the overall results. Furthermore, the Vermejo CCAA will add over 160 stream kilometers of occupied Rio Grande cutthroat trout habitat when it is completed, approximately 50% of which have been restored to date. Our status assessment model is not able to take this into account for future forecasting. While we have found that the Vermejo CCAA satisfies our PECE criteria and may be considered for future analysis, our model does not currently reflect these anticipated increases in population size and resiliency. If the results did include these conservation efforts the overall probabilities of persistence would be higher than forecasted.

5.3.1 Rangewide Probability of Persistence by Population

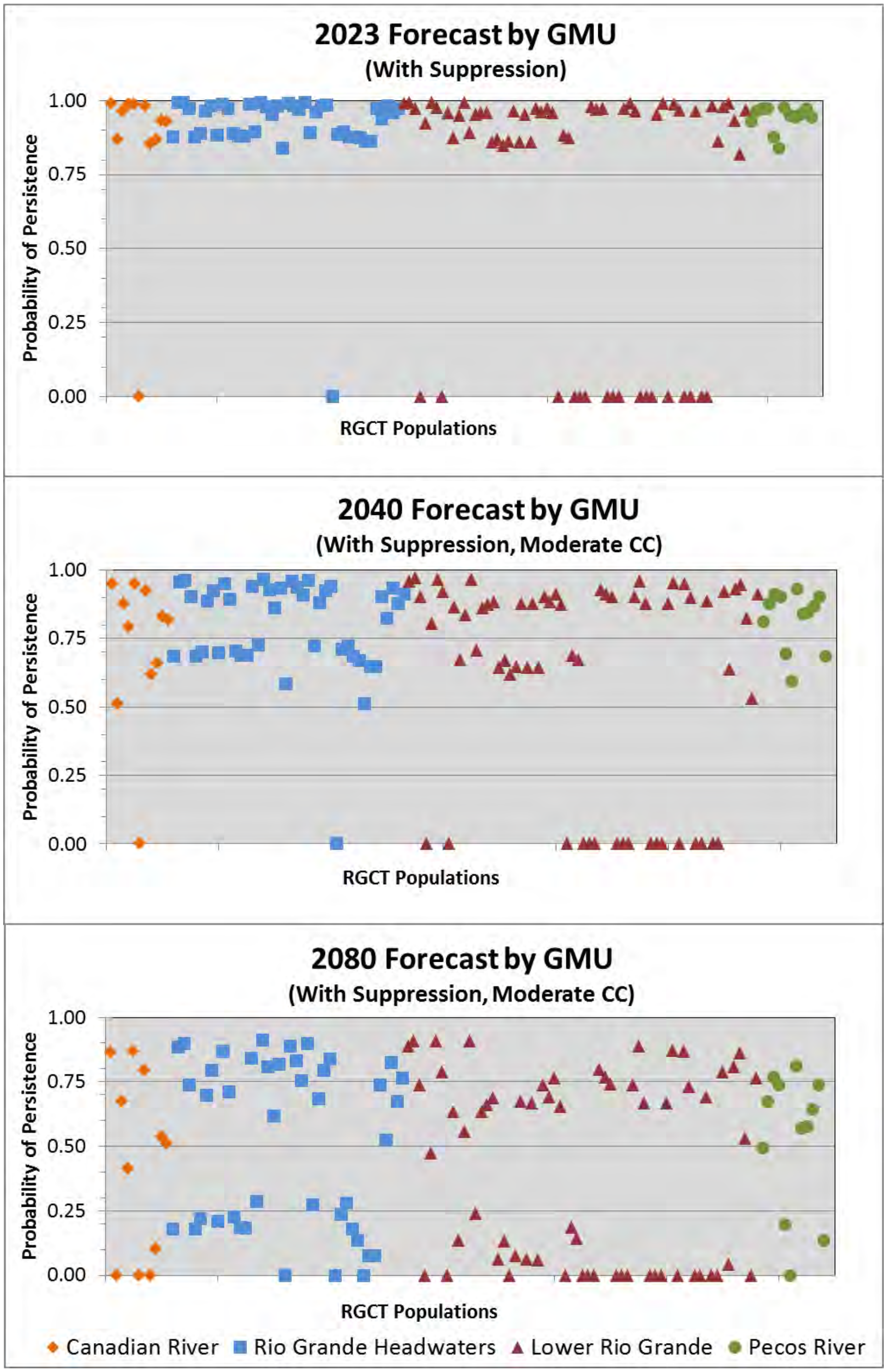

Figure 5. Probability of persistence for each Rio Grande cutthroat trout population. The forecasts include suppression of competing nonnative trout and the 2040 and 2080 forecasts include moderate climate change conditions.

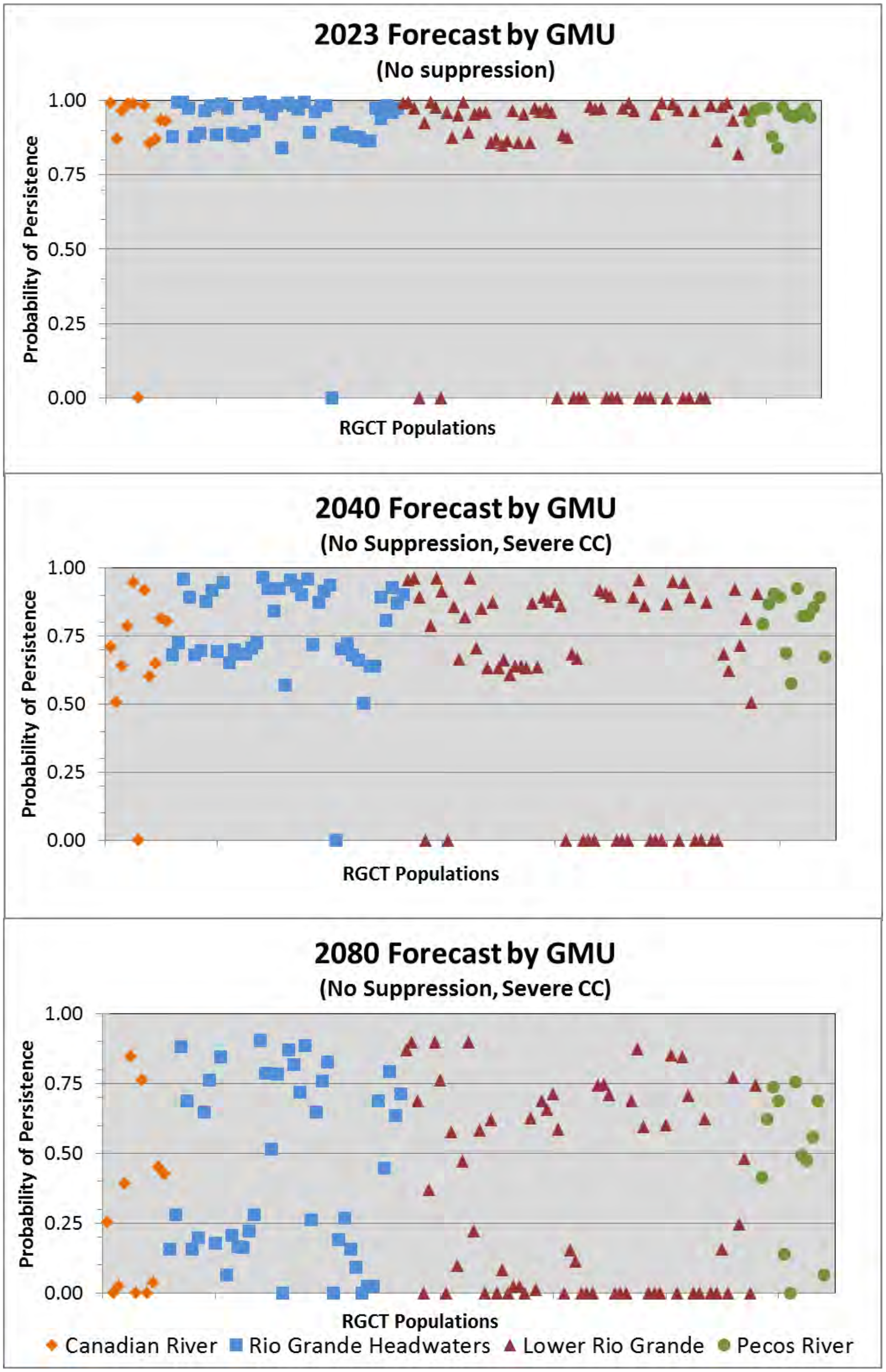

Figure 6. Probability of persistence for each Rio Grande cutthroat trout population. The forecasts include no suppression of competing nonnative trout and the 2040 and 2080 forecasts include severe climate change conditions.

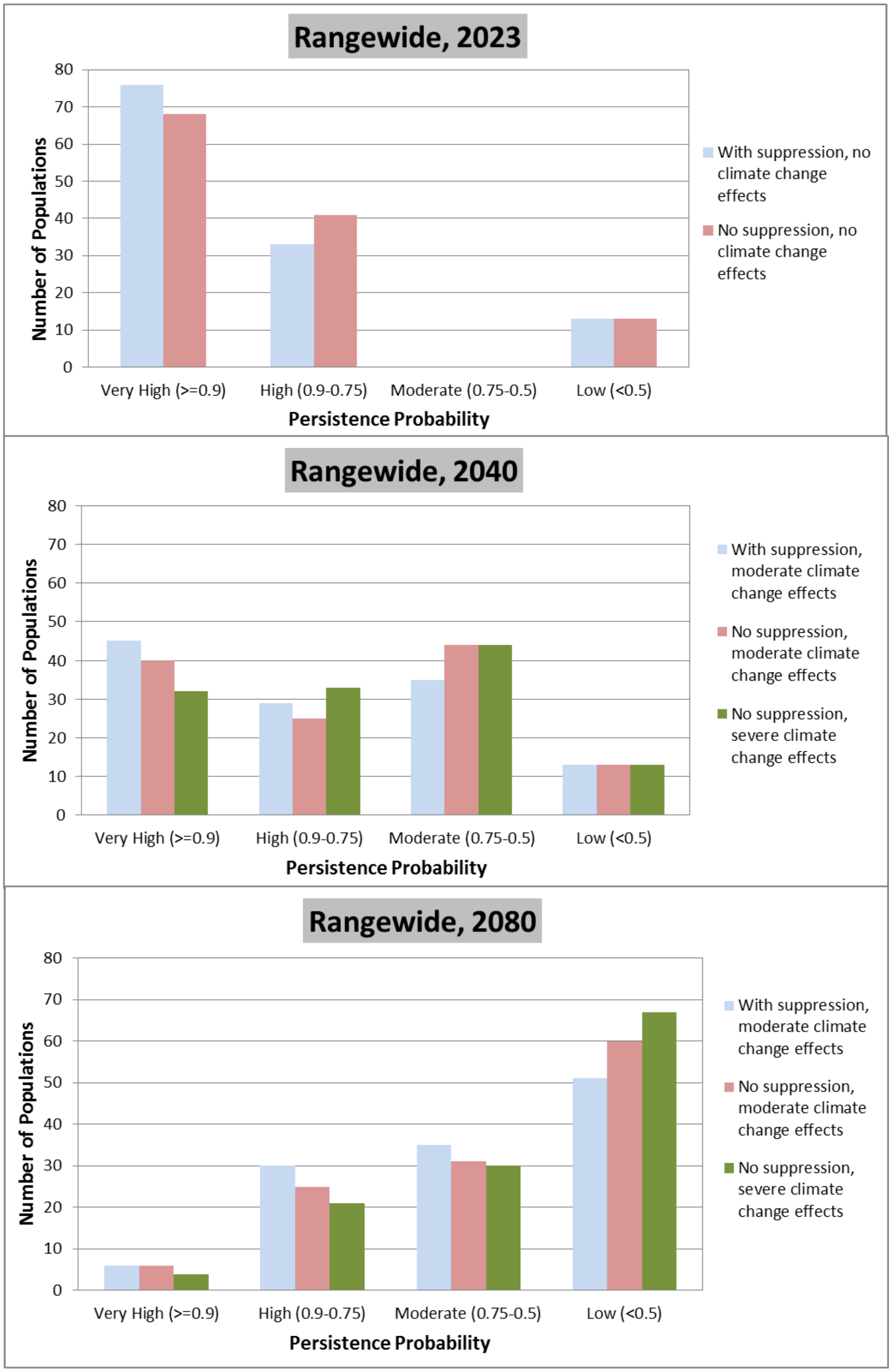

Figure 7. Frequency distributions of Rio Grande cutthroat trout populations rangewide based on their probability of persistence in 2023 (top graph), 2040 (middle graph), and 2080 (bottom graph).

5.3.2 Canadian GMU Populations, Probability of Persistence

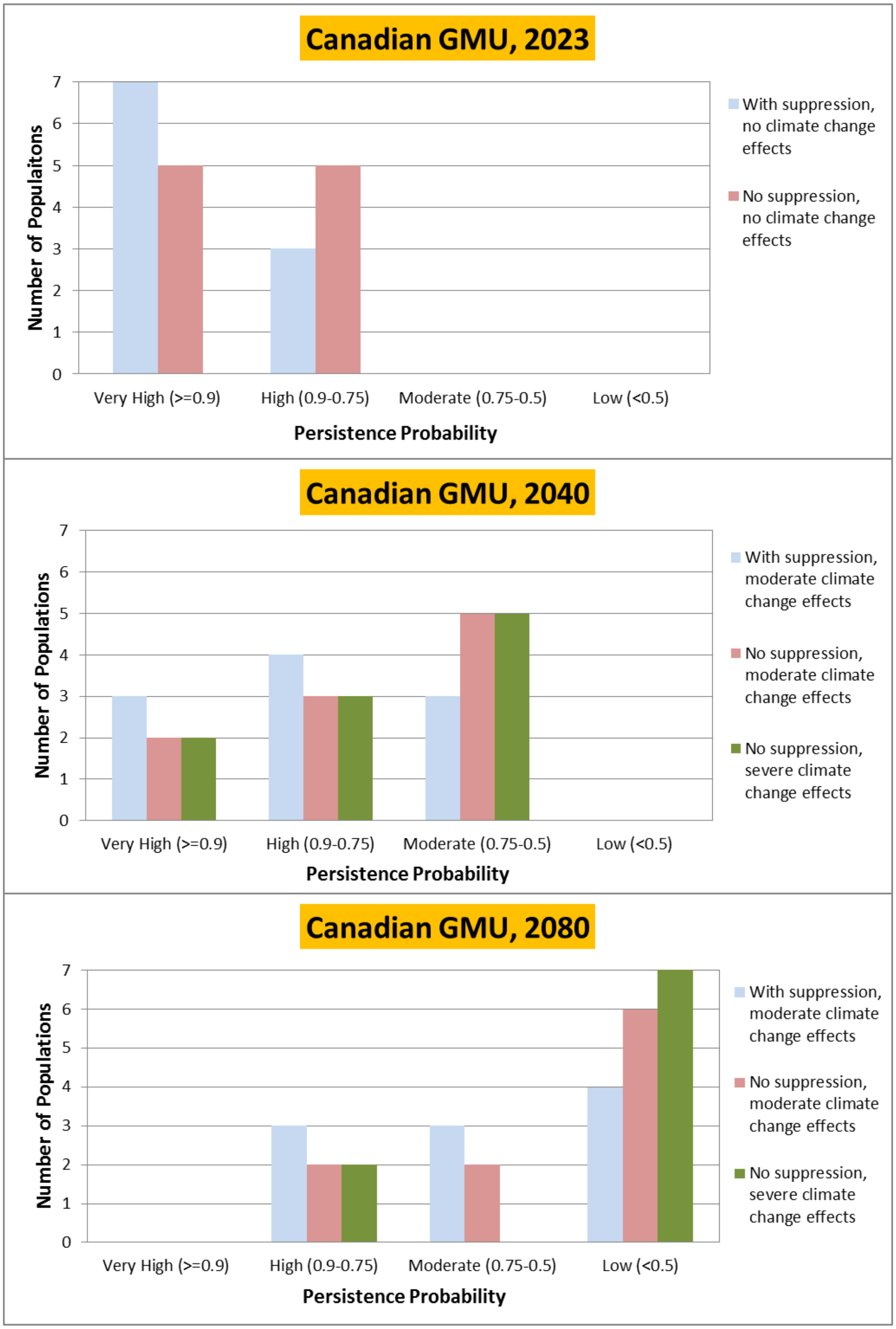

Figure 8. Frequency distributions of Rio Grande cutthroat trout populations in the Canadian GMU based on their probability of persistence in 2023 (top graph), 2040 (middle graph), and 2080 (bottom graph).

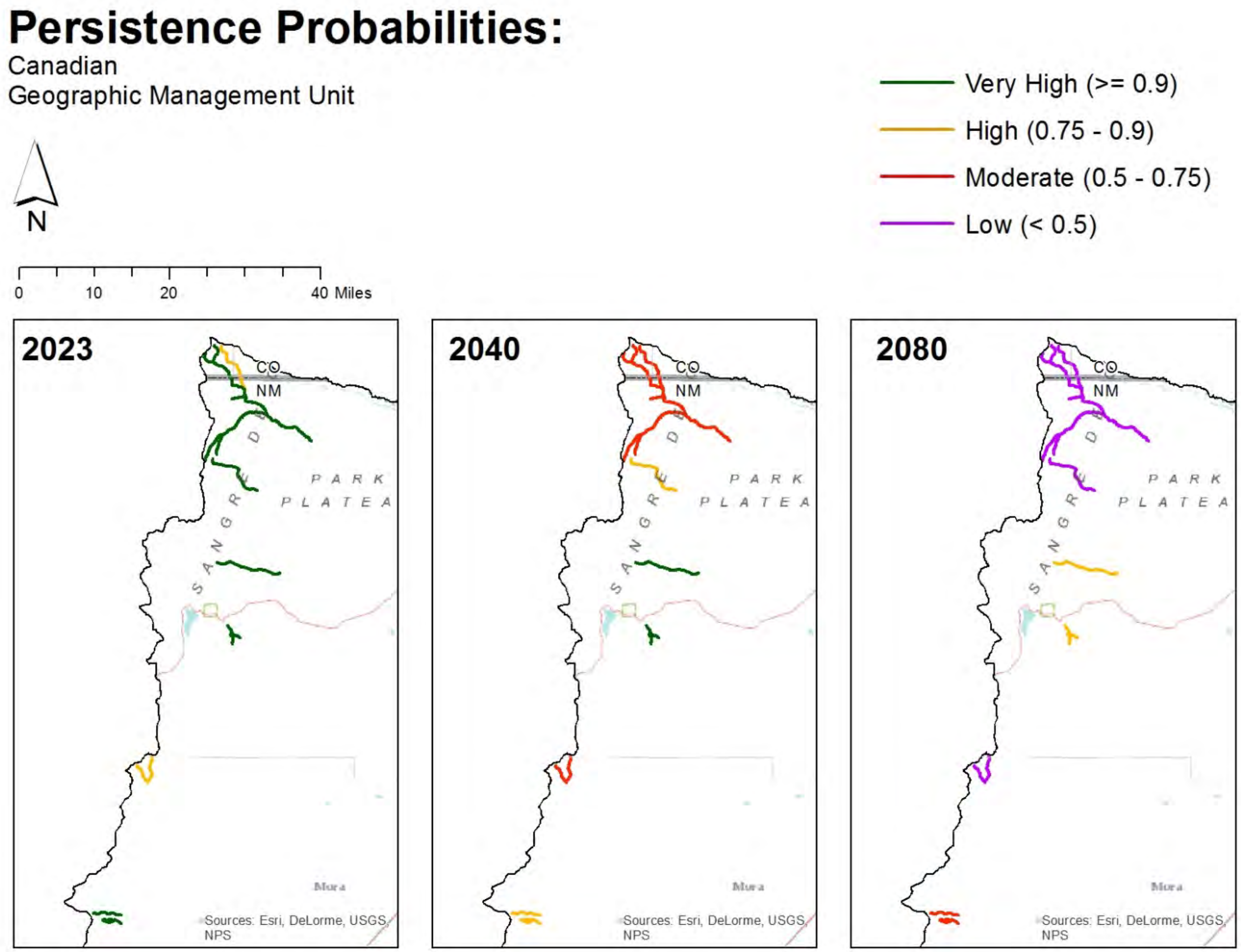

Figure 9. Locations of Rio Grande cutthroat trout populations in the Canadian GMU based on their probability of persistence in 2023, 2040, and 2080. The 2023 map reflects results with competitive nonnative trout suppression. The 2040 and 2080 maps reflect results with no competitive nonnative trout suppression and moderate climate change effects.

5.3.3 Rio Grande Headwaters GMU Populations, Probability of Persistence

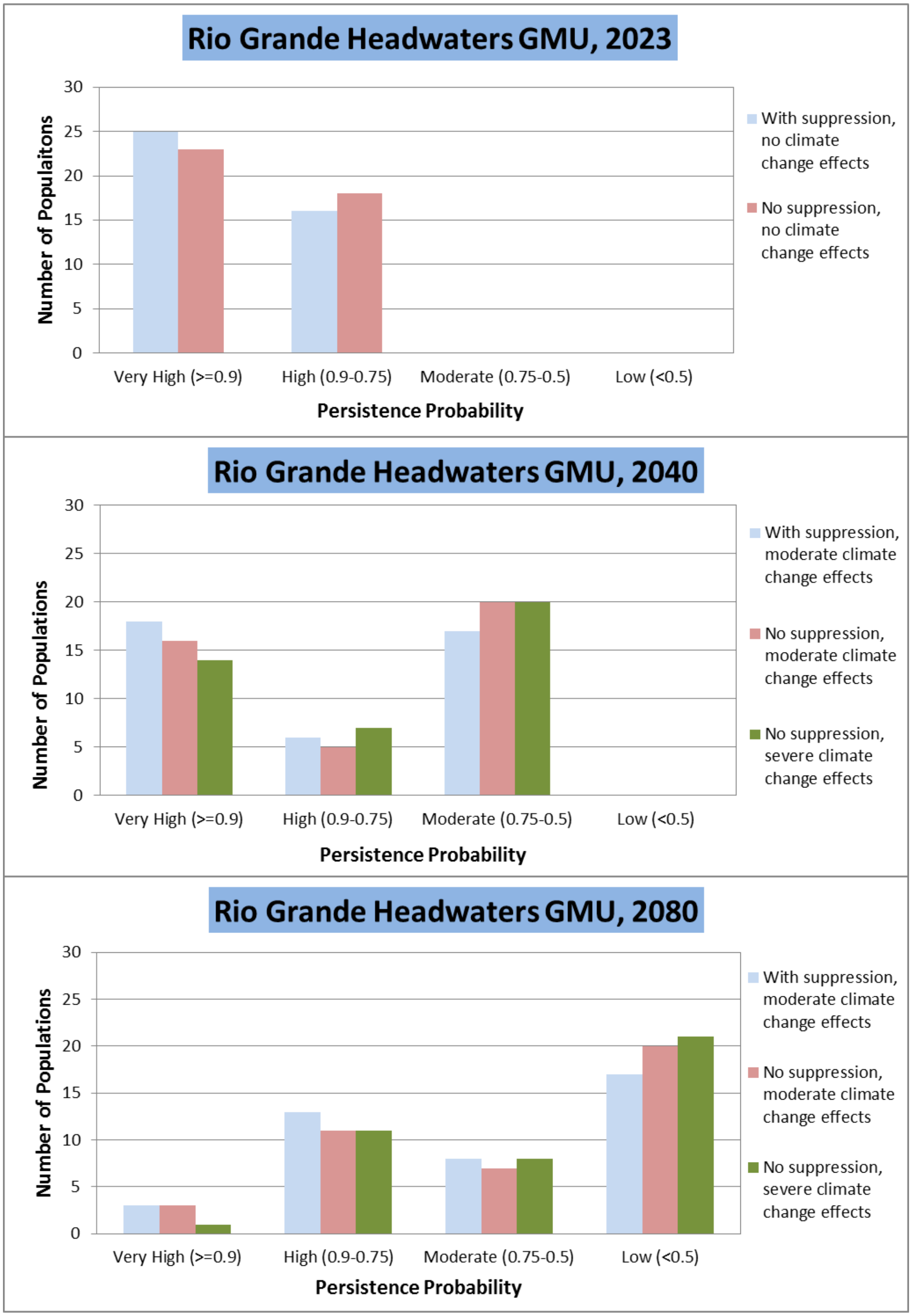

Figure 10. Frequency distributions of Rio Grande cutthroat trout populations in the Rio Grande Headwaters GMU based on their probability of persistence in 2023, 2040, and 2080.

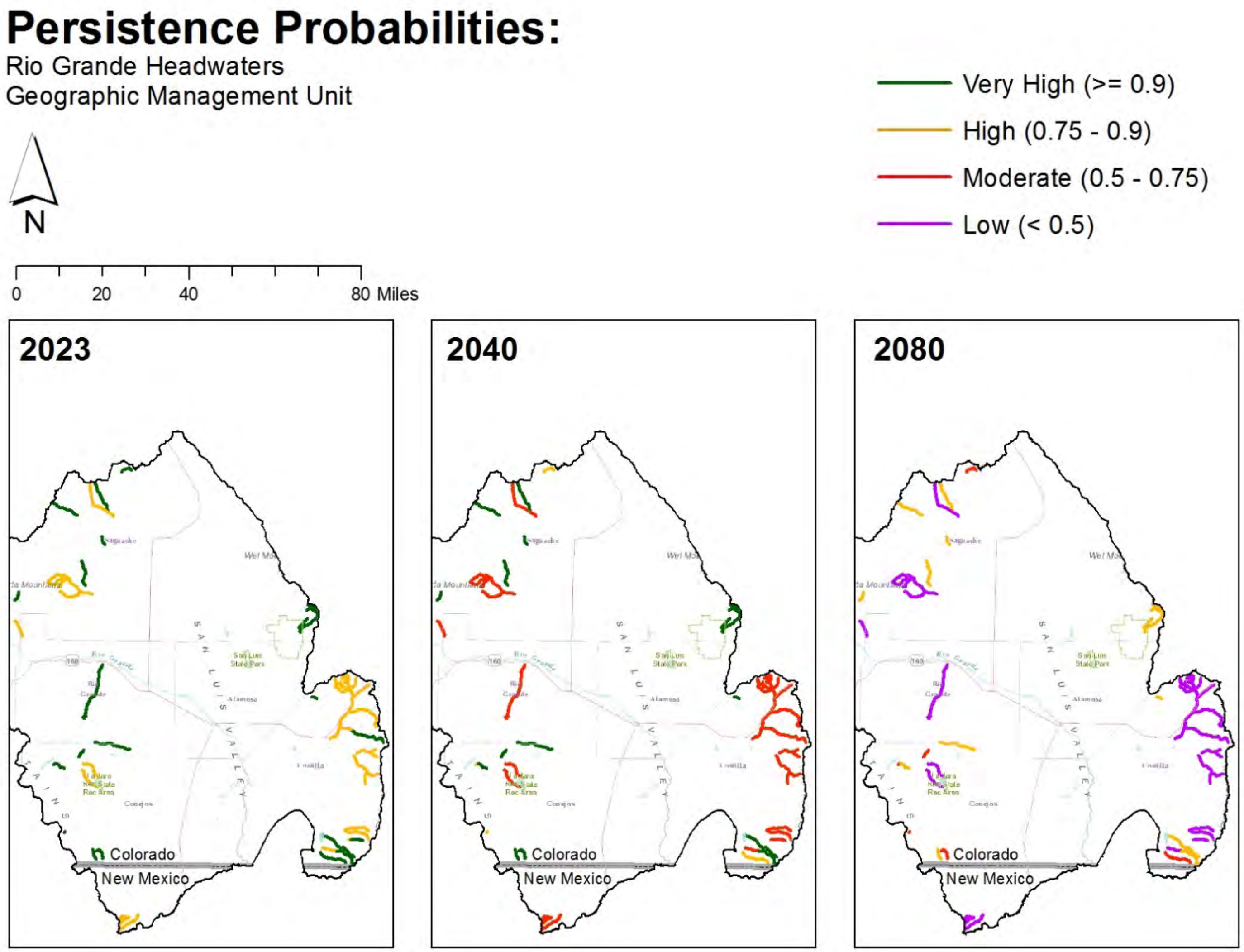

Figure 11. Locations of Rio Grande cutthroat trout populations in the Rio Grande Headwaters GMU based on their probability of persistence in 2023, 2040, and 2080. The 2023 map reflects results with competitive nonnative trout suppression. The 2040 and 2080 maps reflect results with no competitive nonnative trout suppression and moderate climate change effects.

5.3.4 Lower Rio Grande GMU Populations, Probability of Persistence

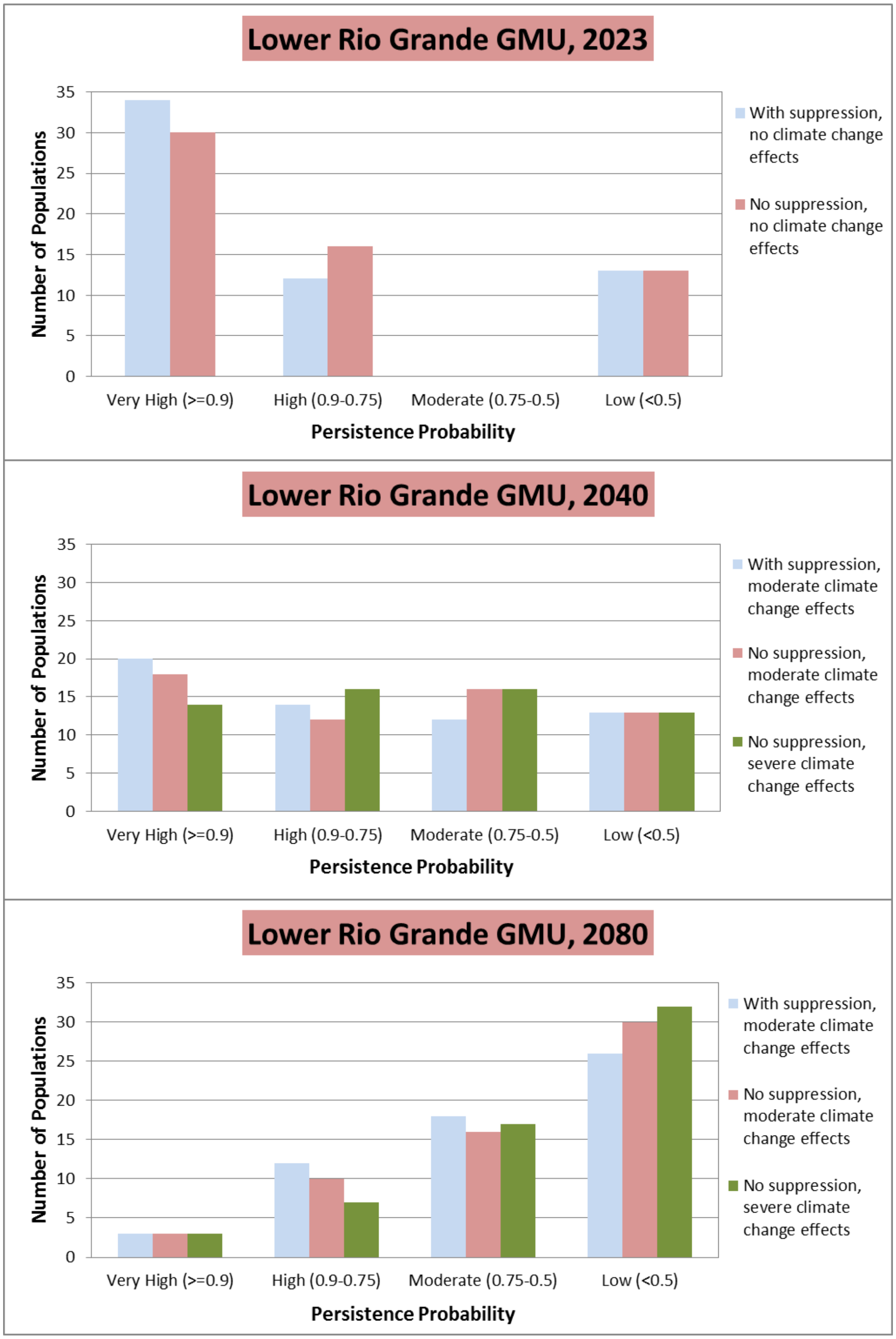

Figure 12. Frequency distributions of Rio Grande cutthroat trout populations in the Lower Rio Grande GMU based on their probability of persistence in 2023, 2040, and 2080.

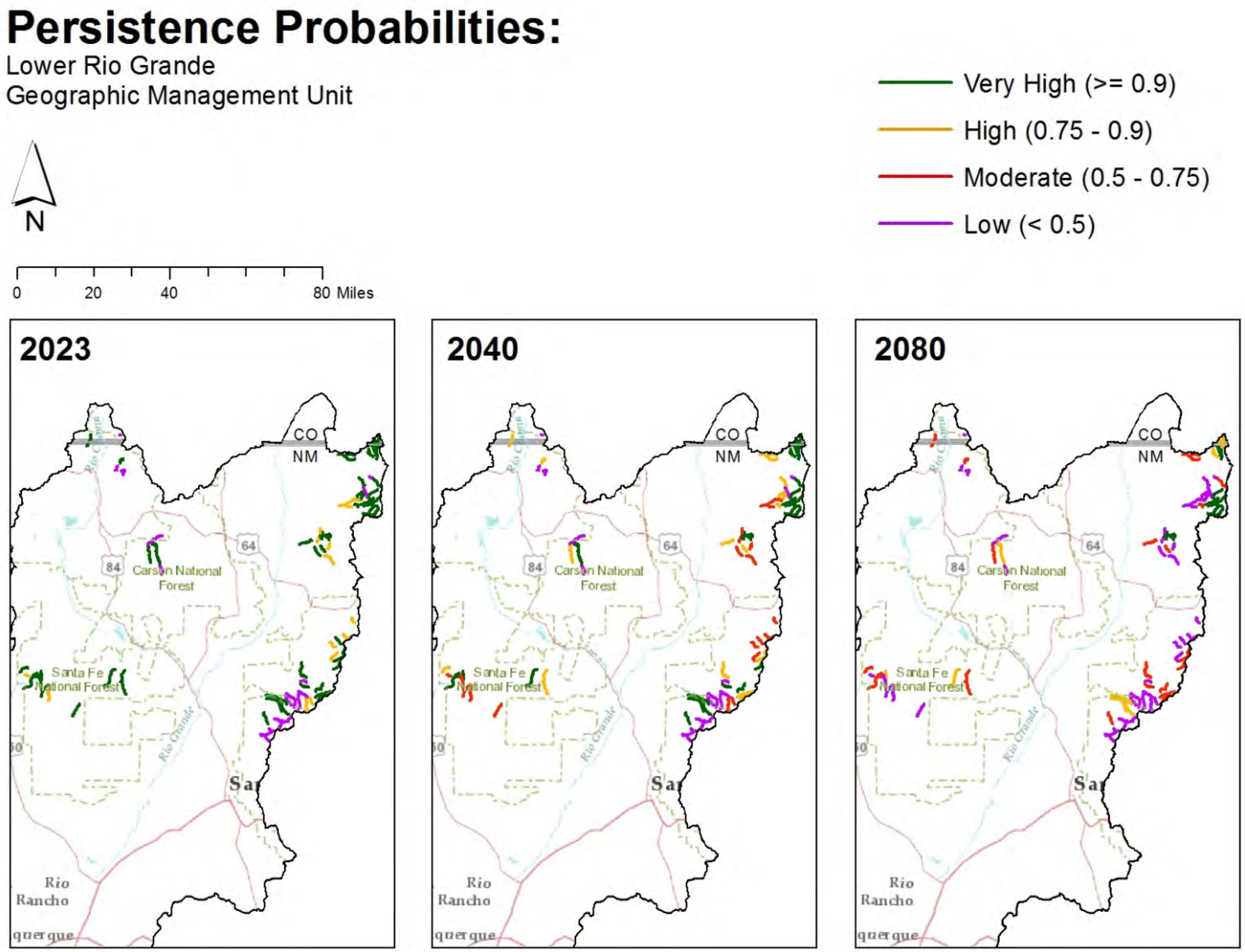

Figure 13. Locations of Rio Grande cutthroat trout populations in the Lower Rio Grande GMU based on their probability of persistence in 2023, 2040, and 2080. The 2023 map reflects results with competitive nonnative trout suppression. The 2040 and 2080 maps reflect results with no competitive nonnative trout suppression and moderate climate change effects.

5.3.5 Pecos GMU Populations, Probability of Persistence

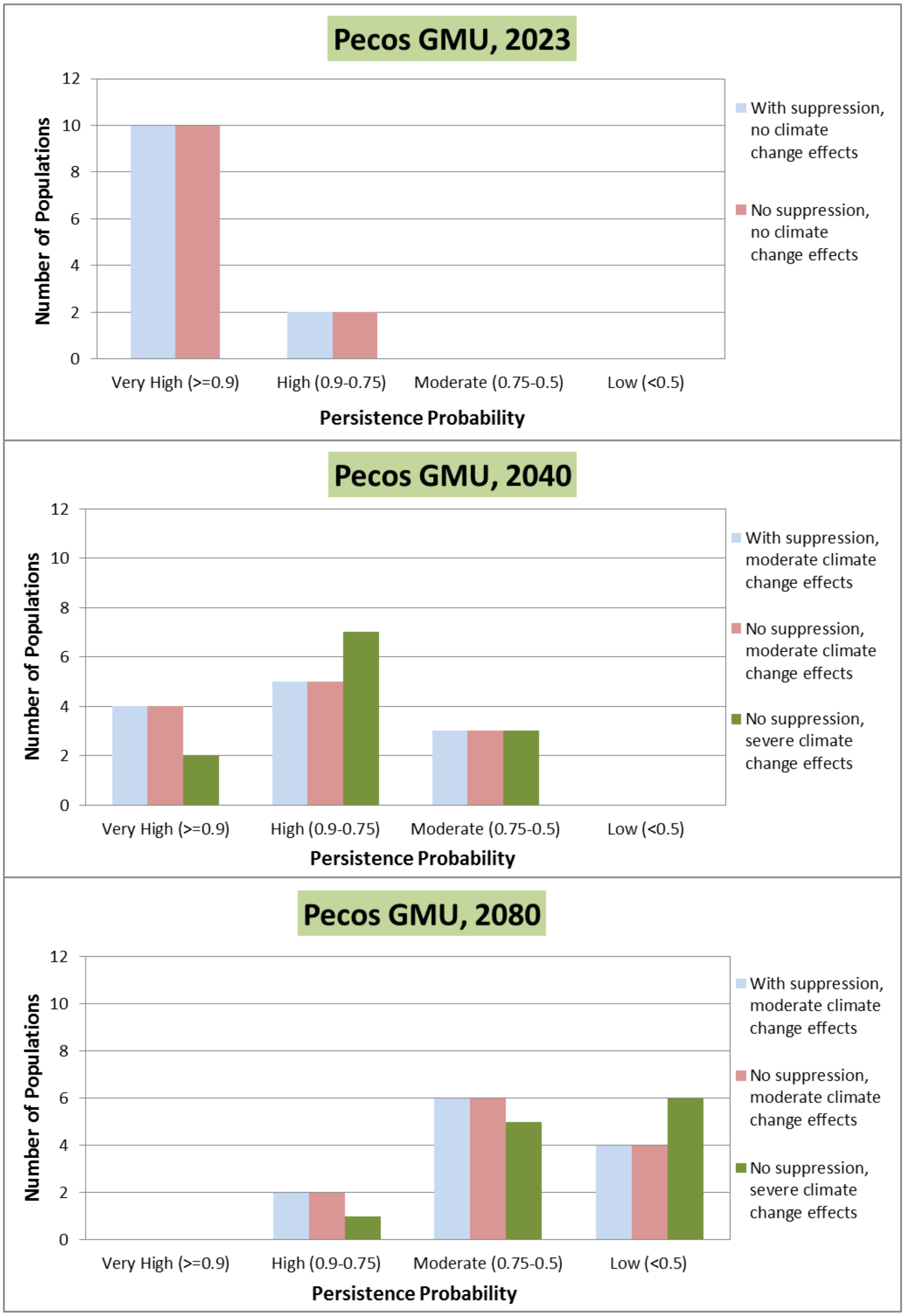

Figure 14. Frequency distributions of Rio Grande cutthroat trout populations in the Pecos GMU based on their probability of persistence in 2023, 2040, and 2080.

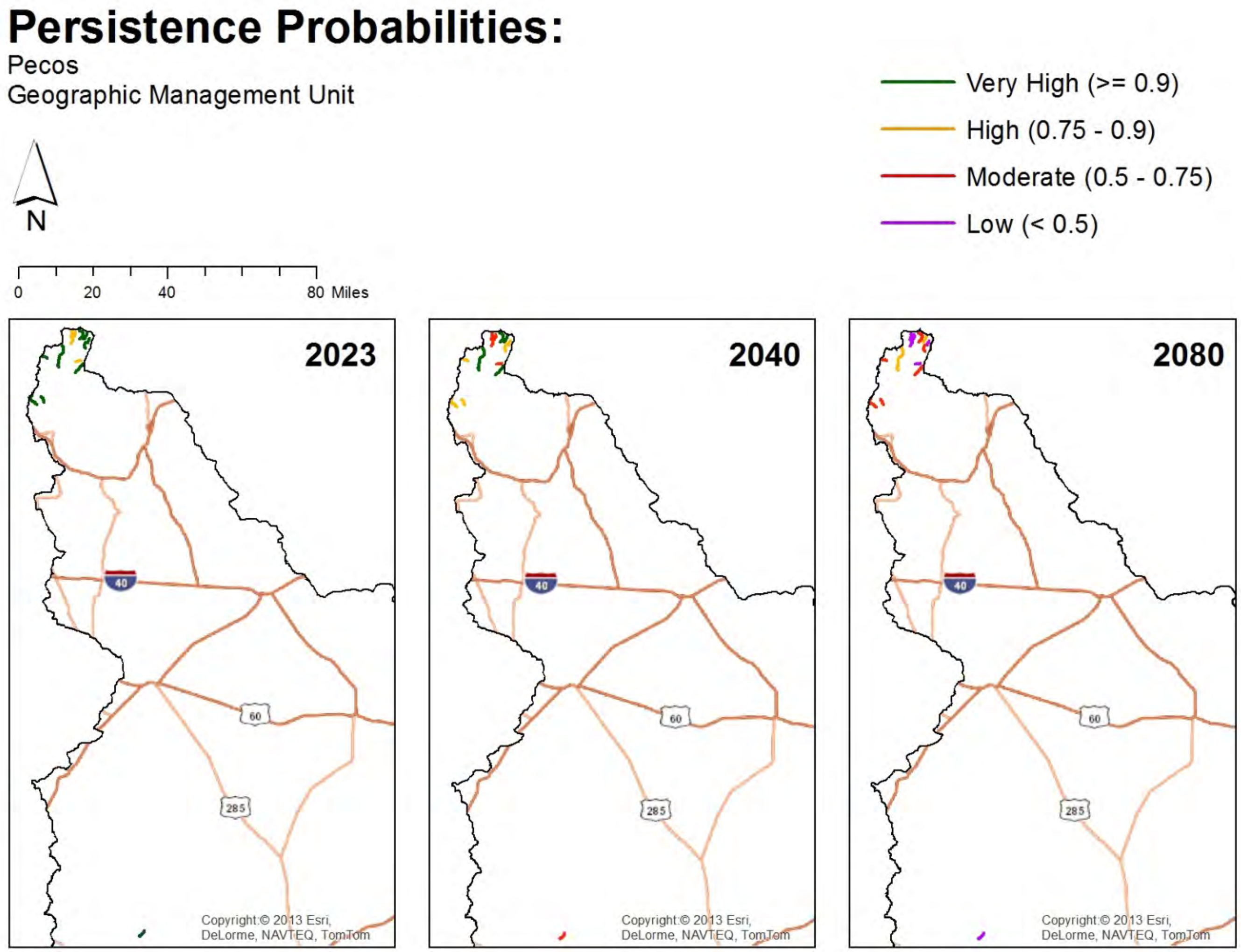

Figure 15. Locations of Rio Grande cutthroat trout populations in the Pecos GMU based on their probability of persistence in 2023, 2040, and 2080. The 2023 map reflects results with competitive nonnative trout suppression. The 2040 and 2080 maps reflect results with no competitive nonnative trout suppression and moderate climate change effects.

5.4 Results: Module 2, Population Survival

The rangewide results of the population survival estimate are provided in Figure 16 for each of the 9 scenarios identified in Table C12 of Appendix C. There are currently 122 extant conservation populations as of 2013. Our analysis suggests that by 2023 the number of populations surviving (that is, forecasted to be persisting and not extirpated) ranges between 104 and 131; by 2040 the range is between 86 and 148; and by 2080 the range is between 50 and 132 populations surviving (Figure 16).

The same results are broken down geographically by GMU in Figures 17 and 18 and Table 4. We displayed the output based on 3 of our scenarios to show a range of estimates (Table 3). The low estimate is scenario 2 (worst case estimate with low management and severe climate change effects) (Appendix C, Table C12). The high estimate is scenario 7 (best case with high management and moderate climate change effects) (Appendix C, Table C12). The Canadian GMU currently has 10 extant populations and by 2080 is forecasted to have between 3 (worst case) and 14 (best case) populations surviving (intermediate case, 6) (Figure 17, Table 4). The Pecos GMU currently has 12 extant populations and by 2080 is forecasted to have between 5 and 16 populations surviving (intermediate, 8) (Figure 17, Table 4). The Rio Grande Headwaters GMU currently has 41 extant populations and by 2080 is forecasted to have between 21 and 55 populations surviving (intermediate, 27) (Figure 18, Table 4). The Lower Rio Grande GMU currently has 59 extant populations and by 2080 is forecasted to have between 21 and 47 populations surviving (intermediate, 28) (Figure 18, Table 4).

Table 3. Summary of three population survival scenarios. Results are displayed in the population survival module, below. These three scenarios represent the overall best, intermediate, and worst cases evaluated in the model.

Scenarios		Climate Change	Nonnative Suppression	Population Simulation	Population Restoration
2	Worst Case	Severe	No	Lower 95% Conf. Interval	Low
6	Intermediate Case	Moderate	No	Mean	Low
7	Best Case	Moderate	Yes	Upper 95% Conf. Interval	High

5.4.1 Rangewide Forecasts

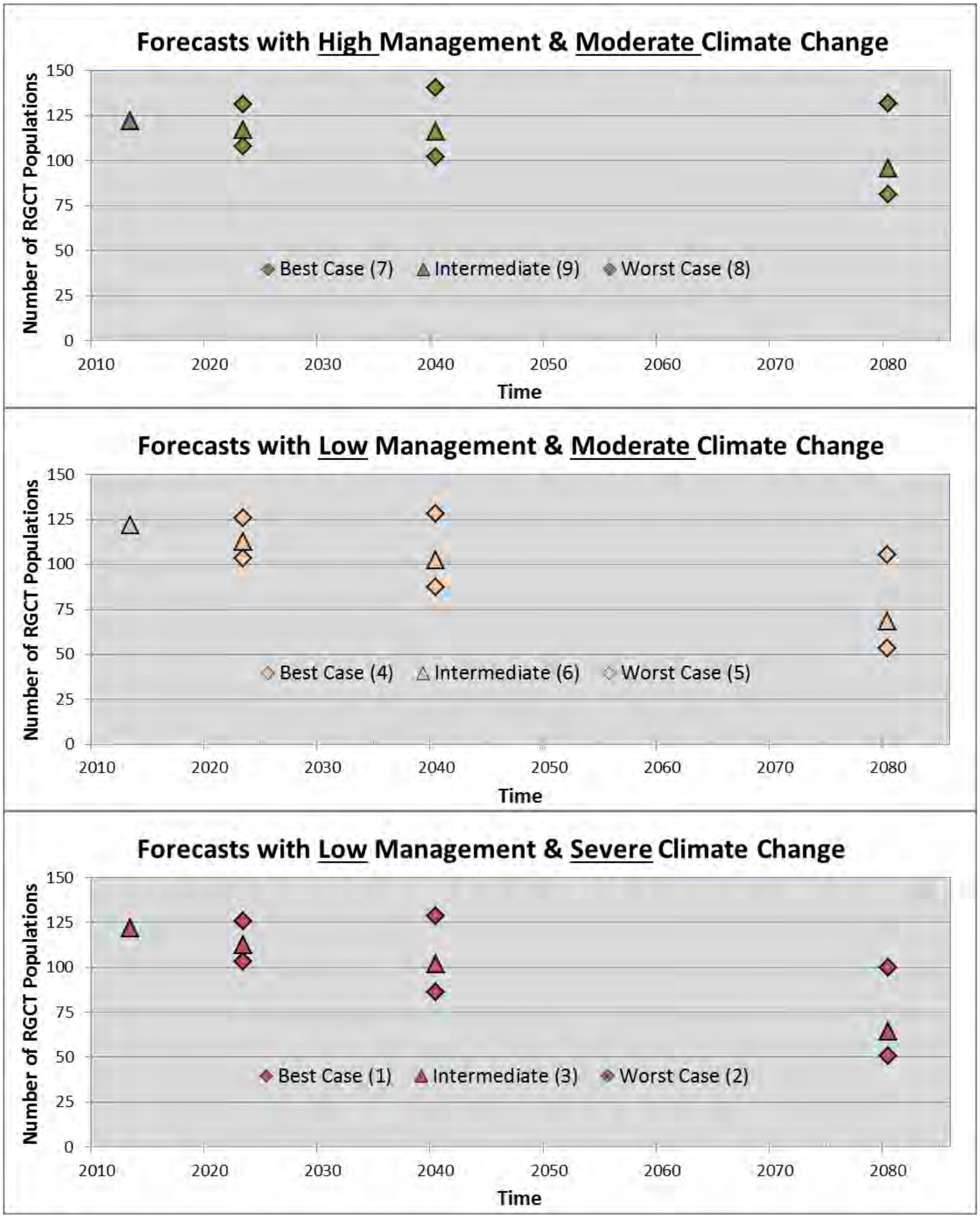

Figure 16. Range of forecasted number of surviving Rio Grande cutthroat trout populations in 2023, 2040, and 2080. Top graph contains scenarios 7-9; center graph contains scenarios 4-6; and bottom graph contains scenarios 1-3 (Appendix C, Table C12). Each graph represents the best, intermediate, and worst cases for the specified level of management and climate change.

5.4.2 Forecasts by GMU

Table 4. Range of forecasted number of surviving Rio Grande cutthroat trout populations in 2023, 2040, and 2080 by GMU. Scenarios represented are found in Appendix C, Table C12.

Canadian GMU			
	Scenarios		
Year	Best (7)	Intermediate (6)	Worst (2)
2013	10	10	10
2023	13.8	10.2	8.5
2040	14.5	9.5	6.6
2080	13.5	5.6	3.1

Pecos GMU			
	Scenarios		
Year	Best (7)	Intermediate (6)	Worst (2)
2013	12	12	12
2023	15.8	12.3	10.9
2040	16.9	11.8	9.5
2080	15.6	8.3	4.8

Rio Grande Headwaters GMU			
	Scenarios		
Year	Best (7)	Intermediate (6)	Worst (2)
2013	41	41	41
2023	49.2	44.2	41.0
2040	55.7	39.5	34.5
2080	55.3	26.8	21.1

Lower Rio Grande GMU			
	Scenarios		
Year	Best (7)	Intermediate (6)	Worst (2)
2013	59	59	59
2023	51.4	45.9	43.0
2040	52.6	41.5	35.5
2080	46.6	27.9	21.4

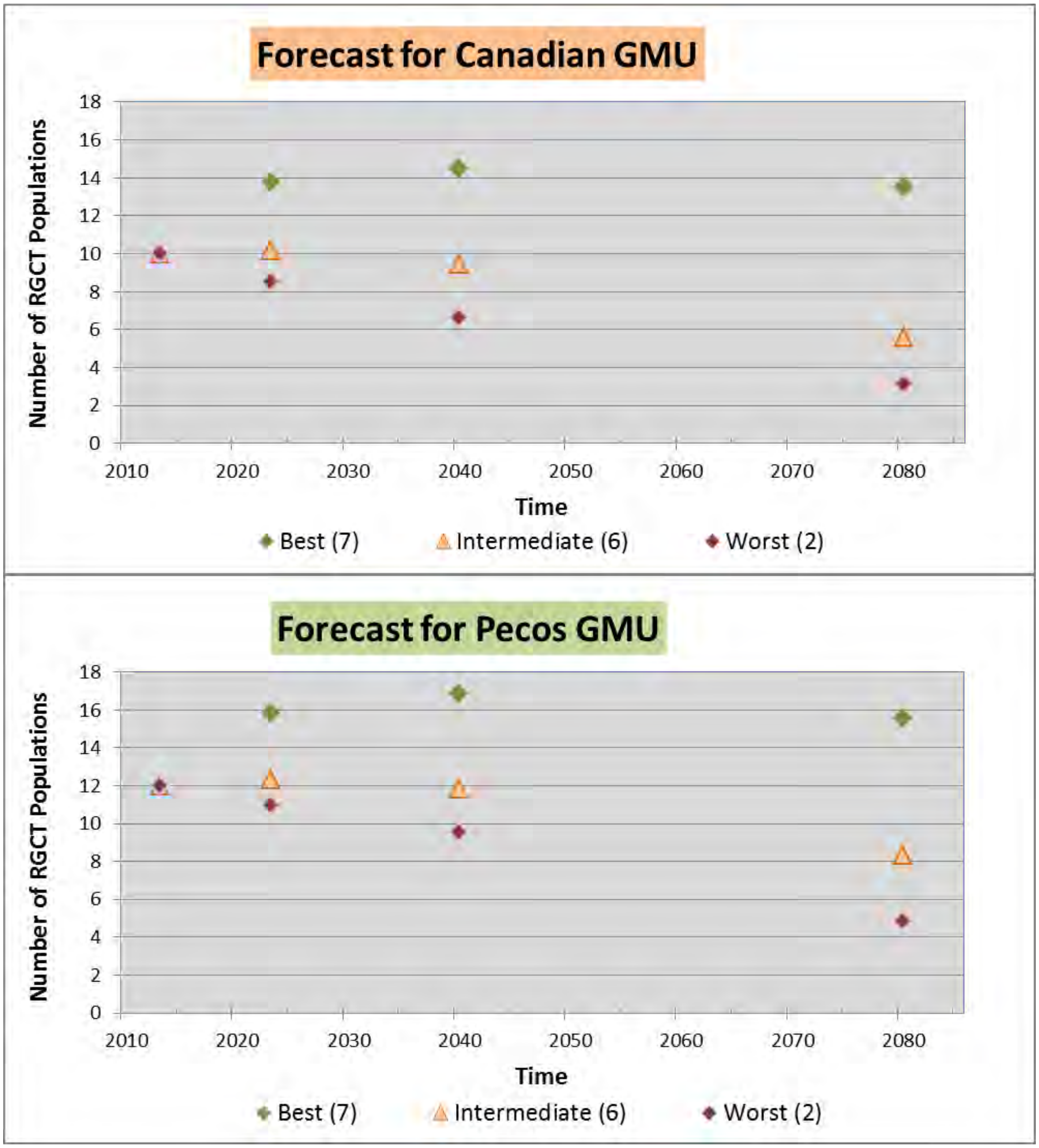

Figure 17. Range of forecasted number of surviving Rio Grande cutthroat trout populations in 2023, 2040, and 2080 in Canadian (top graph) and Pecos (bottom graph) GMUs. Best, intermediate, and worst estimates are from scenarios 7, 6, and 2, respectively (Appendix C, Table C12).

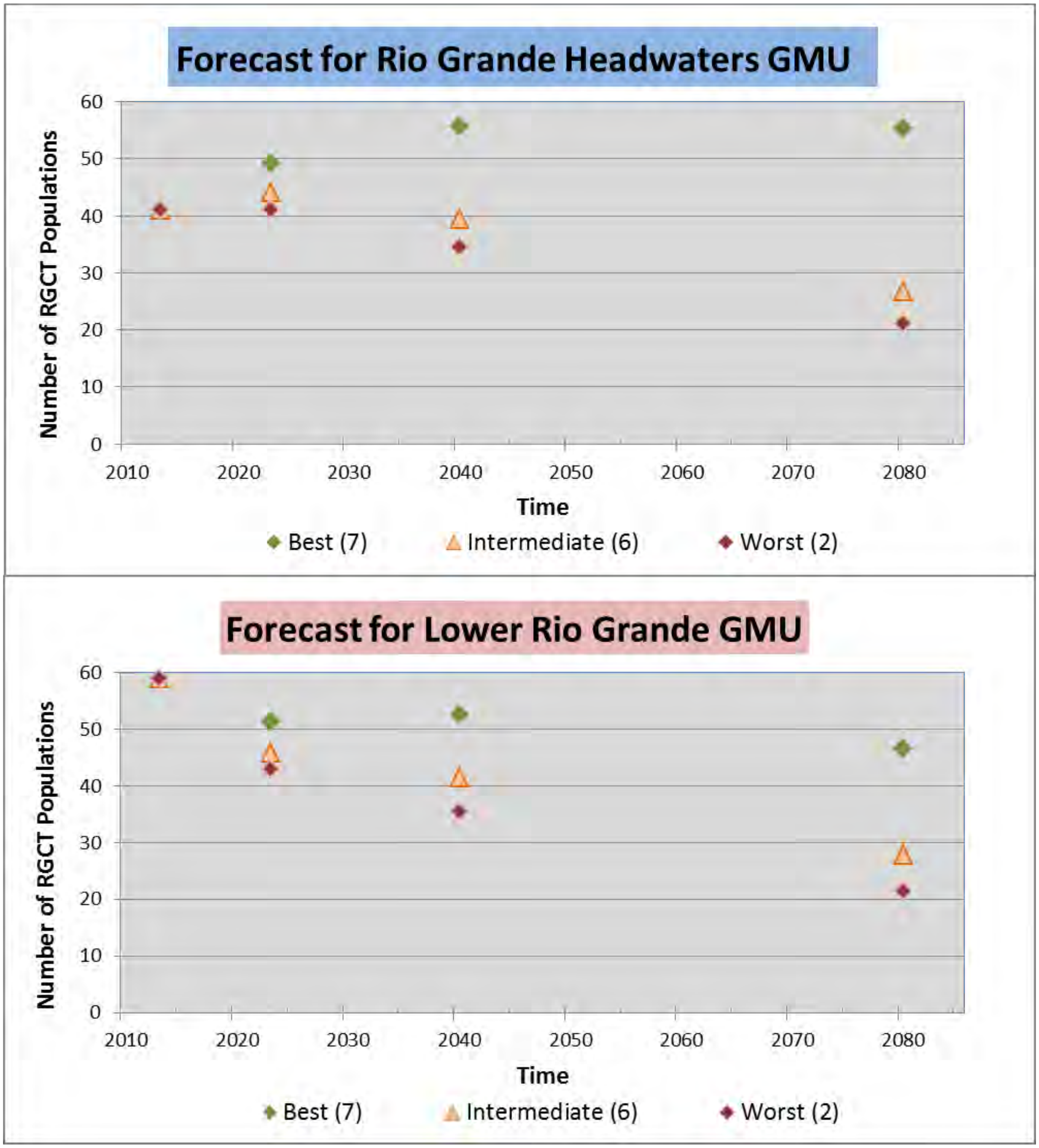

Figure 18. Range of forecasted number of surviving Rio Grande cutthroat trout populations in 2023, 2040, and 2080 in Rio Grande Headwaters (top graph) and Lower Rio Grande (bottom graph) GMUs. Best, intermediate, and worst estimates are from scenarios 7, 6, and 2, respectively (Appendix C, Table C12).

5.5 Results: Stream Length Forecasting

For the results of forecasting the total occupied stream lengths, we plotted the historical, current, and forecasted stream lengths over time (Figure 19). The historical data (estimated 10,696 stream km) was plotted as 1905 just to provide a temporal context on the graph (Alves *et al.* 2008, p. 8, indicates historical was circa 1800). We displayed the output based on 2 of our scenarios to show a range of estimates (worst case, scenario 3, and best case, scenario 9).

The current (2013) estimate for total stream kilometers occupied by Rio Grande cutthroat trout is 1,149 km (about 11% of historical totals). By 2040, we estimate the range of occupied stream kilometers (based on the estimated number and length of surviving populations) to be between 1,076 and 1,292 km (10.1% to 12.1% of historical totals). By 2080, we estimate the range of occupied stream kilometers to be between 722 and 1,186 km (6% to 11.1% of historical totals)[5].

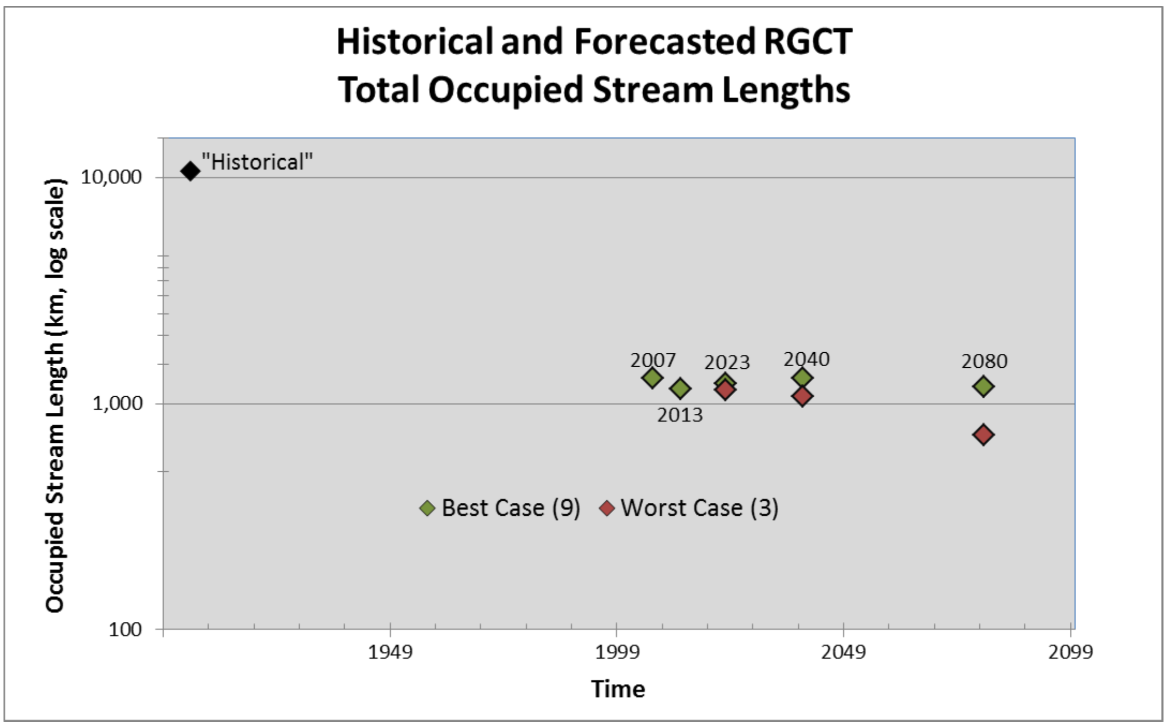

Figure 19. Historical, current, and forecasted total stream lengths estimated to be occupied by Rio Grande cutthroat trout. Historical estimate is plotted as the year 1905 just for display purposes. Low estimate and high estimate use scenarios 3 and 9 (Appendix C, Table C12).

[5] Note the discussion in *Appendix C, Methods, Occupied Stream Length Forecasting* regarding the large uncertainties and low confidence in these forecasted estimates of occupied stream lengths.

5.6 Viability Discussion

We defined viability as a description of the ability of a species to persist over time and thus avoid extinction. “Persist” and “avoid extinction” mean that the subspecies is expected to sustain populations in the wild beyond the end of a specified time period. We are defining the Rio Grande cutthroat trout viability by characterizing the status of the subspecies in terms of its resiliency, redundancy, and representation. Assessing these conditions does not result in a threshold determination (i.e., the subspecies is or is not resilient), but instead we present the results as a risk analysis that reflects our understanding of the relationship between the subspecies’ condition, the risk factors it faces, and a range of forecasted possible outcomes in terms of the probability of persistence in the future at the population and subspecies, rangewide, level.

To evaluate the viability Rio Grande cutthroat trout we first determined conceptually what the subspecies needs for viability. We have summarized these needs in Table 5 (Column 2) beginning with what populations need for resiliency. We then assessed the current condition of the subspecies based on how those needs currently are or are not being met at the population and rangewide scales (Table 5, Column 3). Finally, we used our status assessment model (Appendix C) to forecast the possible future conditions of the subspecies based on the number of populations expected to persist given our understanding of the risks faced by each of the current populations and the expectations for future restoration of populations (Table 5, Column 4). The following discusses our results organized around each of the 3Rs.

Table 5. Overall summary of species status assessment for Rio Grande cutthroat trout. ("RG" = Rio Grande, "pop's" = populations)

3 R's	NEEDS	CURRENT CONDITION	FUTURE CONDITION (VIABILITY)
Resiliency: Population ***(large populations to withstand stochastic events)***	• Large Effective Population Sizes (effective population sizes >500 are best). • Long Streams for Habitat (streams greater than 9.65 km are best). • Free of Nonnative Trout (mainly rainbow and brown trout) and Disease (whirling). • High Quality Habitat (water temps < critical summer maximums).	• 122 Extant Populations across range. * 55 (45%) of populations are currently in the best or good condition *(based on absense of nonnative trout, effective population size, and occuppied stream length)* * 67 (55%) of populations are currently in fair or poor condition.	• Status assessment model estimates probability of persistence for each population based on risks from: * Effective Population Size. * Nonnatives (hybridization, competition) and Disease. * Wildfire and Stream Drying . * Water Temperature Increase. • Included climate change considerations for increased risks.
Resiliency: Subspecies ***(populations to withstand stochastic events)***	• Multiple interconnected resilient populations.	• About 11% of historic range remains occupied due to past impacts from nonnatives. • Populations are isolated (16 populations have some connectedness).	• 2080 model forecasts future populations persisting; results range depending on future management level and severity of climate change: reporting **best to worst (intermediate)** results: * **50 to 132 (69)** populations rangewide. • Limited opportunity to regain interconnectedness of populations (due to pervasive nonnative trout).
Redundancy ***(number and distribution of populations to withstand catostrophic events)***	• Multiple highly resilient populations within each of the 4 Geographic Management Units (GMUs).	• Current total number of populations persisting by GMU: * 41 pop's in RG Headwaters GMU. * 59 pop's in Lower RG GMU. * 10 pop's in Canadian GMU. * 12 pop's in Pecos GMU.	• 2080 model forecasts for future populations persisting by GMU: * **21 to 55 (27)** pop's in RG Headwaters. * **21 to 47 (28)** pop's in Lower RG. * **3 to 14 (6)** pop's in Canadian. * **5 to 16 (8)** pop's in Pecos.
Representation ***(genetic and ecological diverstiy to maintain adaptive potential)***	• Genetic variation exists between 1) Two GMUs in the Rio Grande Basin and 2) Two GMUs in Canadian and Pecos River Basins. • Unknown ecological variation, but we used GMUs as proxy.	• Current total populations persisting by Watershed: * 100 pop's in Rio Grande Basin. * 22 pop's in Candadian and Pecos GMUs.	• 2080 model forecasts for future populations persisting by watershed: * **42 to 102 (55)** pop's in Rio Grande Basin. * **8 to 30 (14)** pop's in Canadian and Pecos GMUs.

5.6.1 Resiliency

Resiliency is having sufficiently large populations for the subspecies to withstand stochastic events. Stochastic events are those arising from random events such as severe weather or wildfire. We measured resiliency at the population scale for the Rio Grande cutthroat trout by quantifying the persistence probability of each extant population under a range of assumed conditions. The results provide our best estimate of the resiliency of each population. The primary stochastic events facing Rio Grande cutthroat trout include wildfire, drought, and the invasion of nonnative species. The ability of Rio Grande cutthroat trout to withstand these events depends on the severity of the event and the current status of the population, such as the stream size, a surrogate measure of quantity and diversity of habitat. This ability to survive such events, in combination with the likelihood of such events happening, forms the basis of our population resiliency model and the results it produced.

The resiliency of each population is particularly important for the Rio Grande cutthroat trout because of the severe changes it has undergone in recent times. Rangewide, the resiliency of the subspecies has declined substantially due to the large decrease in overall distribution. In addition, the remnant Rio Grande cutthroat trout populations are now mostly isolated to headwater streams due to the fragmentation that has resulted from the historical, widespread introduction of nonnative trout across the range of Rio Grande cutthroat trout. Therefore, if an extant population is extirpated due to a localized event, such as a wildfire and subsequent debris flow, there is little to no opportunity for natural recolonization of that population. This reduction in resiliency results in a lower probability of persistence for the subspecies as a whole. To describe the remaining resiliency of the subspecies, we evaluated the individual populations in detail to understand the subspecies' overall capacity to withstand stochastic events.

The factors threatening these populations generally have a relatively low risk of occurrence; however, if the stochastic events occur, they potentially have a high risk of resulting in substantial effects to a population, which could possibly result in extirpation (see Chapter 4 and Appendix B for a discussion of these factors). This relationship makes determining the cumulative risk of these stressors particularly difficult to assess and predict the outcome. Additionally, we were not able to quantitatively account for all potential synergistic effects between the risk factors due to the limitations in our analytical process. However, our probability of persistence module incorporates the risks in an explicit way to assess the estimated resiliency of the Rio Grande cutthroat trout.

As expected based on our methodology all of the population persistence probabilities decreased over time (Figures 5–15). This is because we built the model such that the risks associated with each factor increase over time in a linear relationship. As a result there are many populations whose probability of persistence decreases substantially by 2080. These results do not necessarily mean that any one of the populations will, in fact, be extirpated by 2080, but they simply reflect the risks that we believe the populations face due to their current conditions and the factors influencing their resiliency.

One of the most important factors affecting these results is the presence of nonnative trout. We assigned a relatively high risk function to populations with co-occurring populations of brown trout, brook trout, or rainbow trout where no management suppression is happening. Fifty populations of Rio Grande cutthroat trout currently co-occur with competitive nonnative trout populations, and five populations co-occur with rainbow trout, so this factor has a large influence on the overall viability of the subspecies. Figure 21 highlights the difference in the resulting probabilities of persistence for populations with and without nonnative trout, as the results cluster into two groups. In addition, 10 populations where nonnative trout co-occur with Rio Grande cutthroat have higher probabilities of persistence because of the active management suppression that is reducing the risk of extirpation of those populations (Figure 21, top graph).

The other important factor in the population resiliency is the occupied stream length. Our model incorporated this metric into two of the risk factors—wildfire and stream drying. It also indirectly affects demographic risks because longer streams generally have larger effective population sizes and for some streams lacking population size data we used stream length to estimate effective population size. There was not a statistically significant relationship between stream length and probability of persistence, although our results indicate a general trend of increasing probabilities of persistence as the stream length increases (Figure 21). The lack of correlation suggests that this factor alone was not the driving factor in determining overall probabilities of persistence, but other factors were important as well.

One of the main areas of uncertainty in our analysis is the potential effects of climate change, which we incorporated into four of the risk factors (hybridizing nonnative trout, wildfire, stream drying, and water temperature). Even under the case of severe climate change, which we estimated as a 40% increase in the risk factors by 2080, the overall results of the analysis were not substantially different compared to the moderate climate change scenarios (Figure 21). This does not necessarily mean that climate change may not be an important concern for the Rio Grande cutthroat trout, but it does reflect our current understanding of the best available information on the risks to the species from factors that may be influenced by future climate change. Given our current understanding and the best available information, the influence of climate change does not appear to be a dominant factor in the future persistence of Rio Grande cutthroat trout populations.

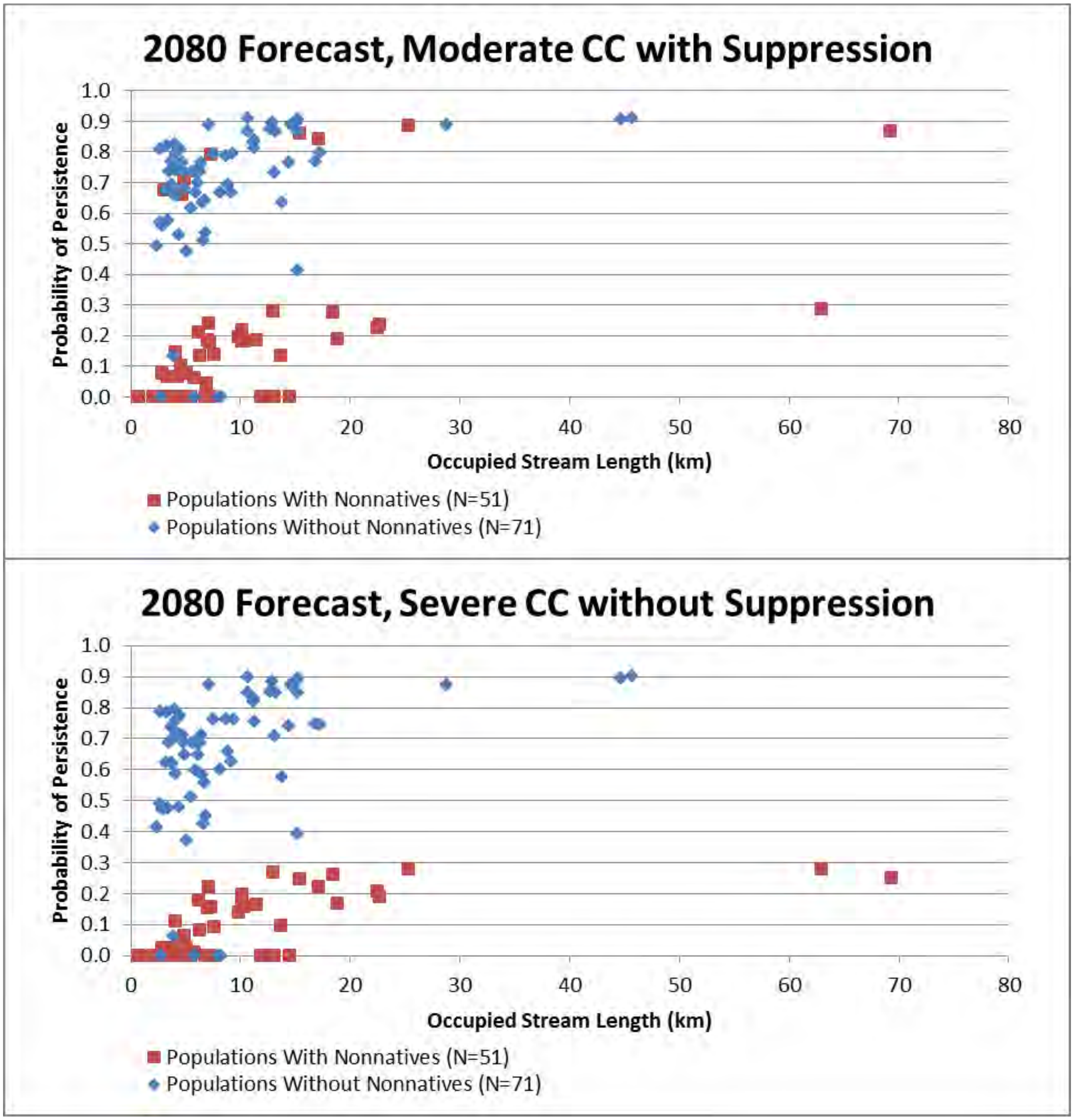

Figure 20. Forecasted probability of persistence of 122 Rio Grande cutthroat trout population compared to occupied stream length under two sets of conditions: moderate climate change effects with suppression of competing nonnative trout (top graph) and severe climate change without suppression of nonnative trout (bottom graph). Populations are designated as those occurring with nonnative trout (blue diamonds) and those not occurring with nonnative trout (red squares). Populations in the upper graph that are co-occurring with nonnative trout and have persistence probabilities greater than 0.6 are those populations with management suppression of nonnative trout.

5.6.2 Redundancy

Redundancy is having sufficient numbers of populations for the subspecies to withstand catastrophic events. A catastrophic event is defined here as a rare destructive event or episode involving many populations and occurring suddenly. The most likely catastrophic event for the Rio Grande cutthroat trout that could affect a substantial portion of the subspecies' range would probably be related to a large-scale hydrologic anomaly, such as an extended drought that changed hydrologic conditions. Wildfire that affected a large portion of the subspecies' range could also result in a catastrophic event. For the Rio Grande cutthroat trout, we measured redundancy by forecasting the number and resiliency of populations distributed across the subspecies' range. The Rio Grande cutthroat trout needs multiple, highly resilient populations across the GMUs to maintain redundancy and high viability. This quality and distribution of populations would provide security to allow the species to withstand future catastrophic events and avoid extinction. The more resilient populations the subspecies has, and the more broadly they are distributed, the greater its redundancy. The subspecies currently has approximately 122 populations distributed across the four GMUs (Table 4), with populations per GMU ranging from 10 to 59.

We used the results of the persistence probabilities along with the number of estimated future restored populations to predict the number and location of future surviving populations by GMU under a range of possible conditions. The results suggest that, depending on the particular scenario considered related to risk factors and restoration efforts, the overall number of populations rangewide surviving by 2080 range from a low of 50 under the worst case scenario to a high of 132 under the best case scenario, with 68 in the intermediate case (Table 4). Some GMUs may decline more than others; for example, our forecasts suggest the Lower Rio Grande GMU could have the largest decline (Figure 16); we estimate the 59 current populations could decline to between 21 and 47 populations by 2080 (Table 4). The GMU with the least populations, the Canadian GMU (with 10 current populations), is forecasted to range between 3 and 14 populations by 2080 (Table 4). Based on our forecasts of persisting populations by 2080, it seems unlikely that a catastrophic event would eliminate the species from an entire GMU, because our forecasts suggest that populations will remain distributed throughout the four GMUs.

5.6.3 Representation

Representation is having the breadth of genetic and ecological diversity of the subspecies to adapt to changing environmental conditions. The only known important genetic structure within the Rio Grande cutthroat trout is between the two GMUs in the Rio Grande basin (Rio Grande Headwaters GMU and Lower Rio Grande GMU) and the other two GMUs (Canadian and Pecos GMUs). Together, the Pecos and Canadian GMUs have some genetic diversity that may be important to maintain for long-term viability. Although we are not aware of any specific ecological diversity across the subspecies' range that might be important for future adaptation, it would be prudent to maintain as much geographic extent of the subspecies range as possible to maintain any potential, but undetected, ecological diversity. To ensure adequate representation, it is important to retain populations in the Canadian and Pecos GMUs to maintain the Rio Grande cutthroat trout's overall potential genetic and life history attributes, buffering the subspecies' response to environmental changes over time. Therefore, we evaluated representation based on the extent of the geographical range as a proxy for considered ecological diversity expected to be maintained in the future as indicated by the populations persisting within each GMU.

We forecasted that the two GMUs in the Rio Grande basin would have between 42 and 102 (intermediate 55) populations continuing to persist in 2080 and that the two GMUs in the Pecos River and Canadian River basins combined would have between 8 and 30 (intermediate 14) populations continuing to persist in 2080 (Table 4). While a potential decline compared to current conditions under the worst and intermediate cases, the important genetic variation across the subspecies range is forecasted by our model to be maintained in 2080. The Canadian and Pecos GMUs together currently have 22 populations of Rio Grande cutthroat trout. Our "worst case scenario" forecast shows a decline in these two GMUs to a total of 8 populations surviving in 2080. This potential decline would be an important trend that indicates an increasing risk to this portion of the range of the subspecies. At the other extreme, with high levels of management actions, the Canadian and Pecos GMUs are forecasted to have as high as 30 populations surviving in 2080. This would represent an increasing trend and a lowering of the overall risk to the Rio Grande cutthroat trout.

In considering the estimated persistence probabilities and their locations, we provide a picture of the future representation of the subspecies potential ecological diversity across its range to 2080 (Figures 5–15). For example, Figures 12 and 19 show the persistence probability of populations in the Lower Rio Grande GMU, where persistence probabilities appear to decline the most over time in our model. The map in Figure 13 would indicate that the variation in persistence probabilities is distributed across the GMU so that none of the risk is associated with any particular geographic area within the GMU. The number of surviving populations by GMU (Figures 15 and 16) also provides an estimate for the future geographic variation that is expected to survive through 2080 and suggests that, even under the worst case scenarios, populations will persist across the range of the subspecies.

5.6.4 Status Assessment Summary

We used the best available information to forecast the likely future condition of the Rio Grande cutthroat trout. Our goal was to describe the viability of the subspecies in quantitative terms that will address the needs of the subspecies in terms of resiliency, redundancy, and representation. We considered the possible future condition of the subspecies out to about 65 years from the present. We considered a range of potential conditions and scenarios that we believe are important influences on the status of the subspecies. Our results describe a range of possible conditions in terms of the probability of persistence of individual populations across the GMUs and a forecast of the number of populations surviving in each GMU.

None of our "worst case scenario" forecasts result in a predicted loss of all of the populations within any of the GMUs. Therefore, at a minimum, our results suggest the subspecies will have persisting populations in 2080 across its range. The most likely scenarios generally show a declining persistence and number of populations over time. However, the rate of this decline, or whether it occurs at all, depends largely on the likelihood of future management actions occurring, the most important of which are the future restoration and reintroduction of populations within the historical range and the control of nonnative trout. While other factors are important to each population, the future management actions will probably determine the future viability of the Rio Grande cutthroat trout.

APPENDIX A - GLOSSARY OF SELECTED TERMS

Anthropogenic– caused or produced by humans.

Basibranchial teeth– teeth found on or at the base of the tongue.

Benthic feeding– eating food found on the stream bottom.

Catastrophic event–a rare destructive event or episode involving many populations and occurring suddenly.

Census population size– the total number of individuals in a population.

Demographic stochasticity–the variability of population growth rates arising from related random events such as birth rates, death rates, sex ratio, and dispersal, which, may increase the risk of extirpation in small populations.

Dorsal fin– fin located on the back of fish

Ecological diversity– the variation in habitats occupied by the species.

Effective population size– a theoretical measure of the number of breeders in the population that contribute to genetic diversity.

Environmental stochasticity–the variation in birth and death rates from one season to the next in response to weather, disease, competition, predation, or other factors external to the population.

Extant–a population that is still in existence.

Extirpation–the loss of a population or a species from a particular geographic region.

Fluvial– of, relating to, or inhabiting flowing water.

Foraging– finding food.

Population fragmentation– a form of population segregation, occurring when populations become separated from other populations of the same species.

Fry– a young, newly hatched fish.

Genetic diversity– the total number of genetic characteristics in the genetic makeup of a species, subspecies, or population.

Genetic drift– the random change in gene frequencies in a population.

Headwaters– a tributary stream of a river close to or forming part of its source.

Headwater capture– a tributary from one watershed joins with a tributary from another.

Hydrology–the movement or distribution of water on the surface and underground, and the cycle involving evaporation, precipitation, and flow.

Inbreeding– the interbreeding of closely related individuals.

Introgression– gene mixing between species.

Lateral line– a system of sense organs along the side of the body of a fish.

Life history– the full range of changes, habits, and behaviors of a living thing over the course of its life.

Morphological–the structure or form of an organism.

Opportunistic feeder– an organism that feeds on whatever food is available.

Persistence– the ability of a population to sustain itself over time.

Piscicide– fish toxicant.

Piscivorous– fish eating.

Predate– to prey upon.

Prescribed burn– the controlled application of fire to a forest to mimic historical wildfire regimes.

Range–the geographic region throughout which a species naturally lives or occurs.

Recruitment– the number of fish growing to maturity in a population.

Redd– a spawning nest built by trout or salmon in the gravel of streambeds.

Redundancy–the ability of a species to withstand catastrophic events.

Repatriation– the process of repopulating an area of historical habitat.

Representation–the ability of a species to adapt to changing environmental conditions.

Resiliency–the ability of the species to withstand stochastic events.

Riffles– a fast flowing, shallow portion of a stream.

Runoff– the flow of water from rain, snowmelt, or other sources over land.

Salmonid– a member of the family Salmonidae, which includes salmon, trout, and whitefish.

Sex ratio– the proportion of males to females in a population.

Spawn– to produce or lay eggs in water.

Stochastic events–arising from random factors such as weather, flooding, or fire.

Sympatry–species occupying overlapping geographic areas.

Taxonomic–the classification of animals and plants.

Thinning– in forestry, the selective removal of trees to improve the health of the forest and reduce wildfire risk.

Viability– a description of the ability of a species to persist over time and thus avoid extinction.

Appendix B

Evaluating Causes and Effects for Rio Grande Cutthroat Trout Species Status Assessment

Template for Cause and Effects Evaluation

THEME: ?			
[ESA Factor(s): ?]	**Analysis**	**Confidence / Uncertainty**	**Supporting Information**
SOURCE(S)	*What is the ultimate source of the actions causing the stressor?*	See next page for confidences to apply at each step.	Literature Citations, with page numbers , for each step.
- Activity(ies)	*What is actually happening on the ground as a result of the action?*		
STRESSOR(S)	*What are the changes in evironmental conditions on the ground that may be affecting the species?*		
- Affected Resource(s)	*What are the resources that are needed by the species that are being affected by this stressor?*		
- Exposure of Stressor(s)	*Overlap in time and space. When and where does the stressor overlap with the resource need of the species (life history and habitat needs)?*		
- Immediacy of Stressor(s)	*What's the timing and frequency of the stressors? Are the stressors happening in the past, present, and/or future?*		
Changes in Resource(s)	*Specifically, how has(is) the resource changed(ing)?*		
Response to Stressors: - INDIVIDUALS	*What are the effects on individuals of the species to the stressor? (May be by life stage)*		
POPULATION & SPECIES RESPONSES	*[Following analysis will determine how do individual effects translate to population and species-level responses? And what is the magnitude of this stressor in terms of species viability?]*		
Effects of Stressors: - POPULATIONS [RESILIENCY]	*What are the effects on population characteristics (lower reproductive rates, reduced population growth rate, changes in distribution, etc)?*		
- SCOPE	*What is the geographic extent of the stressor relative to the range of the species/populations? In other words, this stressor effects what proportion of the rangewide populations?*		
Effects of Stressors: - SPECIES (Rangwide) [REDUNDANCY]	*What are the expected future changes to the number of populations and their distribution across the species' range?*		
Effects of Stressors: - SPECIES (Rangwide) [REPRESENTATION]	*What changes to the genetic or ecology diversity in the species might occur as a result of any lost populations?*		
RISK OF EXTIRPATION 2023	*Based on this analysis, how do we characterize the risk of populations being extirpated from this stressor over the next 10 years (by 2023)?*		

This table of Confidence Terminology explains what we mean when we characterize our confidence levels in the cause and effects tables on the following pages.

Confidence Terminology	Explanation
Highly Confident	We are more than **90% sure** that this relationship or assumption accurately reflects the reality in the wild as supported by documented accounts or research and/or strongly consistent with accepted conservation biology principles.
Moderately Confident	We are **70 to 90% sure** that this relationship or assumption accurately reflects the reality in the wild as supported by some available information and/or consistent with accepted conservation biology principles.
Somewhat Confident	We are **50 to 70% sure** that this relationship or assumption accurately reflects the reality in the wild as supported by some available information and/or consistent with accepted conservation biology principles.
Low Confidence	We are less than **50% sure** that this relationship or assumption accurately reflects the reality in the wild, as there is little or no supporting available information and/or uncertainty consistency with accepted conservation biology principles. Indicates areas of high uncertainty.

THEME: Demographic Risk			
[ESA Factor(s): E]	**Analysis**	**Confidence / Uncertainty**	**Supporting Information**
SOURCE(S)	The source of demographic risks comes mainly from the result of having small population sizes. Small population sizes in streams isolated from other populations are a legacy from the loss of areas occupied by Rio Grande cutthroat trout due to the past invasion of nonnative trout.	**Moderately confident**	Rieman and Allendorf 2001 Baalsrud 2011 p. 1
- Activity(ies)	**Historic:** Most small populations received immigrants from other populations, and genetic risk would be small. Isolated populations that were cut off from others may have experienced genetic drift, inbreeding depression, and perhaps local extirpations. **Current:** Nearly all RGCT populations are isolated from one another, and small populations with little genetic diversity are more vulnerable to extirpation by other factors. **Future:** Populations are likely to remain isolated except in areas where large, interconnected populations are being restored (ie, the Costilla system on Vermejo Park Ranch)	**Moderately confident** that historically, interconnected populations rarely experienced strong genetic drift **Highly confident** that populations are very isolated currently and are likely to remain so.	Fausch et al. 2006, p. 8 Peterson et al. 2008a, p. 559 Fausch et al. 2009, p. 861
STRESSOR(S)	Genetic drift and inbreeding depression in small populations can lead to an inability to adapt to changing environmental conditions and put populations at higher risk of extirpation due to other risk factors.	**Highly confident**	Rieman and Allendorf 2001
- Affected Resource(s)	Genetic diversity of populations and population sizes		
- Exposure of Stressor(s)	Where RGCT populations are small (generally with an effective population size of less than 50), the populations are exposed to the stressors associated with demographic risks. Those populations with an effective population size greater than 500 have no exposure to the stressor. Populations with effective population sizes between 50 and 500 have some exposure to the stressor.	**Somewhat confident**	Allendorf et al. 1997, p. 142, 143 Rieman and Allendorf 2001 Cook et al. 2010, p. 1508

THEME: Demographic Risk			
[ESA Factor(s): E]	**Analysis**	**Confidence / Uncertainty**	**Supporting Information**
- Immediacy of Stressor(s)	**Historic:** Small populations were likely rarely exposed to this stressor. **Current:** Those conservation populations that are currently very small and are not being augmented by managers are exposed to the stressor. **Future:** Small populations will continue to be exposed to the genetic effects of small population sizes in the future.	**Historic: Moderately confident** **Current and Future: Highly confident** that small populations may be experiencing genetic drift	Fausch et al. 2006, p. 8 Peterson et al. 2008a, p. 559 Fausch et al. 2009, p. 861
Changes in Resource(s)	Genetic drift and inbreeding depression in small populations can lead to an inability to adapt to changing environmental conditions, although some very small populations have been known to persist for decades.	**Moderately confident**	Rieman and Allendorf 2001 Cook et al. 2010, p. 1508
Response to Stressors: **- INDIVIDUALS**	More inbred individuals with less individual genetic diversity are expected to be less fit than less inbred individuals with more individual genetic diversity.	**Moderately confident**	
POPULATION & SPECIES RESPONSES			
Effects of Stressors: **- POPULATIONS [RESILIENCY]**	Small population sizes are at greater risk from reduced genetic diversity, decreasing a population's ability to adapt to environmental changes, possibly leading to extirpation of the population from other factors. Small populations are also at greater risk from extirpation due to simple demographic processes, accumulation of mildly deleterious mutations, and inbreeding depression. Small populations also have a higher likelihood of extirpation from other risk factors. This is because a population with a low number of individuals is more likely to be completely lost due to a negative event than a population with a larger number of individuals.	**Moderately confident**	Rieman and Allendorf 2001

THEME: Demographic Risk			
[ESA Factor(s): E]	**Analysis**	**Confidence / Uncertainty**	**Supporting Information**
- SCOPE	**Historic:** RGCT populations were rarely isolated from one another and likely only occasionally experienced this stressor. **Current and Future:** See population resiliency model for number of populations with a small effective population size. This stressor can occur rangewide. To our knowledge, no populations of any native trout have been extirpated by demographic risk alone; instead, demographic factors exacerbate the risk of extirpation by other factors.	**Historic: Moderately confident** **Current and Future: Highly confident** in number of populations experiencing a small effective population size.	Alves et al. 2008 RGCT status assessment model
Effects of Stressors: - SPECIES (Rangwide) [REDUNDANCY]	If populations are lost in the future, then overall redundancy will continue to decline.	**Highly confident**	
Effects of Stressors: - SPECIES (Rangwide) [REPRESENTATION]	Any future loss of populations will continue to reduce overall genetic and ecological diversity of the species, further limiting the subspecies' representation.	**Moderately confident**	
RISK OF EXTIRPATION 2023	**Very small populations** have a moderate risk of extirpation due to the exacerbating factor of demographic effects by 2023. **Large populations** have no risk of extirpation due to the exacerbating factor of demographic effects by 2023. See Appendix C for projections of extirpation risk over longer time frames.		

THEME: Nonnative Hybridizing Trout			
[ESA Factor(s): C,E]	**Analysis**	**Confidence / Uncertainty**	**Supporting Information**
SOURCE(S)	Historic stocking of nonnative trout for recreational angling throughout western US.	**Highly confident.** Stocking is well documented.	Flebbe 1994, p 657 Dunham et al. 2002, pg 377 Dunham et al. 2004, pp. 6, 7
- Activity(ies)	**Historic** nonnative stocking programs. **Current and future** unauthorized anthroprogenic movement of fish. (Purposeful, authorized nearby current stocking is only of triploid rainbow trout, which are unable to reproduce.) **Current and future** failure of fish barriers. **Future** conservation strategy restores populations, maintains current barriers, and builds new fish barriers.	**Highly confident** about historic stocking and barrier failure. **Low confidence** in the extent of unauthorized movement of nonnative trout. **Moderate confidence** in maintenance of current barriers and construction of new ones.	Young et al. 1997, p. 240 Peterson and Fausch 2003 Conservation Agreement 2013, pp. 7, 8 Conservation Strategy 2013, pp. 24-25
STRESSOR(S)	Nonnative rainbow trout and other subspecies of cutthroat trout mate with RGCT and produce hybridized offspring. The genetic distinctiveness of Rio Grande cutthroat trout can be lost through hybridization.	**Highly confident** that hybridization occurs based on extensive literature and past population responses. The exact extent is site-dependent.	Rhymer and Simberloff 1996 Allendorf et al. 2004, p. 1205 Boyer et al. 2008, p. 666
- Affected Resource(s)	Genetic integrity of RGCT populations.		
- Exposure of Stressor(s)	Overall, where rainbow trout and nonnative subspecies of cutthroat trout occur, RGCT are exposed to these stressors. See population resiliency assessment for stream-by-stream exposure.	Historic: **Highly confident** about past exposure of nonnatives (well documented). Current: **Moderately confident** in current assessment of nonnative distribution from states' field collection and RGCT database. **Somewhat confident** that climate warming will increase rainbow trout invasions	Boyer et al. 2008, p. 666 Muhlfeld et al. 2014 RGCT database

THEME: Nonnative Hybridizing Trout			
[ESA Factor(s): C,E]	**Analysis**	**Confidence / Uncertainty**	**Supporting Information**
- Immediacy of Stressor(s)	**Historic:** Nonnative trout introductions (of both hybridizing and competing species) account for 90% range loss of RGCT. **Current:** Those conservation populations currently coexisting with rainbow are either already hybridized or will be soon and are at high probability of being lost to conservation. **Future:** Invasion risk continues for RGCT populations that do not have a fish barrier preventing natural invasion of nonnative trout. Invasion risk more likely as streams warm and spring floods decrease through climate change. Unauthorized human introduction has a constant, low probability of occurrence. Stressors are contained by management actions (no stocking, barrier maintenance/construction, and population monitoring).	**Historic: Moderately confident** **Current: Moderately confident i**n assessment of the extent of nonnatives overlapping with conservation populations **Future: Highly confident** that stressors will continue to be contained through limiting nonnative stocking and barrier maintenance and construction.	Dunham et al. 2002, p. 374 Alves et al. 2008, pg 26 Muhlfeld et al. 2014 RGCT database
Changes in Resource(s)	Hybridization with rainbow trout results in introgression with RGCT genes and produces non-pure trout populations lost to conservation.	**Highly confident**	Rhymer and Simberloff 1996 Allendorf et al. 2004, p. 1205 Boyer et al. 2008, p. 666
Response to Stressors: **- INDIVIDUALS**	Genetic introgression of individuals	**Highly Confident**	
POPULATION & SPECIES RESPONSES			
Effects of Stressors: **- POPULATIONS** **[RESILIENCY]**	Genetic introgression of individuals results in i) the population becomes 'swamped' with nonnative genes and loses its identity as Rio Grande cutthroat trout; ii) nonnative introgression causes loss of local adaptations or maladaptive behavior and therefore increases population extinction risk (outbreeding depression); and iii) nonnative introgression causes reduced fitness due to disruption of locally co-adapted gene complexes, thus increasing population extinction risk. At >10% introgression we do not consider populations to be conservation populations of RGCT. Populations are not immediately affected after nonnative trout are introduced; it can take years (or decades) for RGCT populations to be hybridized, and longer for extirpation to occur.	**Highly confident**	Utah Division of Wildlife 2000 Boyer et al. 2008 Alves et al. 2008 Fausch et al. 2009 Pritchard 2014, pers. comm.

THEME: Nonnative Hybridizing Trout			
[ESA Factor(s): C,E]	**Analysis**	**Confidence / Uncertainty**	**Supporting Information**
- SCOPE	**Historic:** RGCT has been extirpated from about 90% of its historical range primarily due to stressors of nonnatives resulting in the loss of RGCT populations. **Current:** Barriers and stocking of triploid rainbow trout have reduced likelihood of further invasions. Currently 84 conservation populations have complete or partial fish migration barriers, reducing risk of hybridizing species invasion. See population resiliency analysis for geographic locations of RGCT populations related to nonnative trout. **Future:** Continued barrier construction and maintenance wil reduce likelihood of further invasions. Distance from non-triploid rainbow trout populations is a factor in future invasion risk; the farther from a non-triploid rainbow trout (or other nonnative cutthroat trout subspecies) population, the less the risk of future hybridization. Under climate change, rainbow trout are expected to be able to invade further upstream. See RGCT population model for assessment of risk to each population by hybridization. The risk of non-triploid rainbow trout invasion does not vary by GMU.	**Historic: Moderately confident** **Current: Highly confident** **Future: Highly confident**	Alves et al. 2008, pg 26 Muhlfeld et al. 2014 RGCT database RGCT status assessment model
Effects of Stressors: **- SPECIES (Rangwide)** **[REDUNDANCY]**	If future populations are lost due to nonnatives, overall redundancy will continue to decline.	**Moderately confident**	
Effects of Stressors: **- SPECIES (Rangwide)** **[REPRESENTATION]**	Any future loss of populations will continue to reduce overall genetic and ecological diversity of the species, further limiting the subspecies' representation.	**Moderately confident**	
RISK OF EXTIRPATION 2023	Populations characterized as **no risk of hybrid invasion** have no risk of extirpation due to hybridization. Populations **sympatric** with rainbow or Yellowstone cutthroat trout have a very high risk of extirpation due to hybridization. See Appendix C for projections of extirpation risk over longer time frames.		

THEME: Nonnative Competing Trout			
[ESA Factor(s): C,E]	**Analysis**	**Confidence / Uncertainty**	**Supporting Information**
SOURCE(S)	Historic stocking of nonnative trout for recreational angling throughout western US.	**Highly confident.** Stocking is well documented.	Flebbe 1994, p 657 Dunham et al. 2002, pg 377 Dunham et al. 2004, pp. 6, 7
- Activity(ies)	**Historic** nonnative stocking programs: mainly brown trout and brook trout. **Current and future** unauthorized anthroprogenic movement of fish. No purposeful nearby current stocking is occuring. **Current and future** failure of fish barriers can allow new invasions into RGCT populations. **Future** conservation strategy restores populations, maintains current barriers, and builds new fish barriers.	**Highly confident** about historic stocking and barrier failure. **Low confidence** in the extent of unauthorized movement of nonnative trout. **Moderate confidence** in maintenance of current barriers and construction of new ones.	Flebbe 1994, p 657 Harig et al. 2000b Dunham et al. 2002, pg 377 Dunham et al. 2004, pp. 6, 7 Johnson et al. 2009, p. 389 Conservation Agreement 2013 Conservation Strategy 2013
STRESSOR(S)	Nonnative trout compete with and predate on RGCT: 1) COMPETITION. Brown trout and brook trout outcompete RGCT for food and space. 2) PREDATION. Brown trout (and likely brook trout) will eat young RGCT.	**1) Highly confident** that these stressors occur based on extensive literature and past population responses. The exact extent is site dependent. **2) Moderately confident** that brown and brook trout predate upon young RGCT.	Dunham et al. 2002, p. 378 Peterson et al. 2004 Fausch et al. 2006, pp. 9-10
- Affected Resource(s)	1) COMPETITION. Food (insects and small fish) and space (sheltering/feeding habitat). 2) PREDATION. Predator avoidance.		Paroz 2005, p. 34 Shemai et al. 2007, pp. 315, 320, 321 Peterson et al. 2004, pp. 768, 769
- Exposure of Stressor(s)	Overall, where nonnative trout occur, RGCT are exposed to these stressors. Water temperature, fine sediment, and abundance of pools and woody debris may influence nonnative trout invasion. (See RGCT population model for stream-by-stream exposure and risk to competing nonnative species.)	Historic: **Highly confident** about past exposure of nonnatives (well-documented). Current: **Moderately confident** in current assessment of nonnative distribution from states' field collection and trout database.	Shepard 2004, p. 1096 RGCT database RGCT status assessment model

THEME: Nonnative Competing Trout			
[ESA Factor(s): C,E]	**Analysis**	**Confidence / Uncertainty**	**Supporting Information**
- Immediacy of Stressor(s)	**Historic:** Nonnative trout introductions (of both hybridizing and competing species) account for 90% range loss of RGCT. **Current:** Although the majority of range contraction was due to hybridizing nonnative species, competing nonnative trout cooccur with approximately 40% of current populations. Stressors of competition and predation persist for RGCT populations that are currently coexisting with nonnative brown or brook trout. **Future:** Invasion risk continues for RGCT populations that do not have a fish barrier preventing natural invasion of nonnative trout. Brown trout may be able to invade further upstream as stream temperatures warm under climate change, and brook trout may be adversely impacted by the earlier peak flows due to climate change. Both of these effects of climate change on competing nonnative trout are highly uncertain. Unauthorized human invasion has a constant, low probability of occurrence. See "Management Actions" worksheet for a description of how stressors are being contained.	**Historic: Moderately confident** **Current: Moderate Confidence i**n assessment of the extent of nonnatives overlapping with conservation populations **Future: Highly confident** that stressors will continue to be contained through limiting nonnative stocking and barrier maintenance and construction, but low confidence in rate of nonnative invasions.	Dunham et al. 2002, p. 374 Alves et al. 2008, pg 26 RGCT database RGCT status assessment model Fausch 2014, pers. comm.
Changes in Resource(s)	1) COMPETITION. Reduction in availability of food and space, harassment by large competitors. Young RGCT are consistently outcompeted by brook and brown trout. 2) PREDATION. Increased rates of predation of young RGCT.	1) **Highly confident** 2) **Moderately Confident**	Paroz 2005, p. 34 Shemai et al. 2007, pp. 315, 320, 321 Peterson et al. 2004, pp. 768, 769
Response to Stressors: **- INDIVIDUALS**	1) COMPETITION. Competition for food will lower fitness of RGCT individuals because less food causes smaller sizes of individuals and potential for less reproductive output. Competition for space will result in higher mortality and lowered reproductive rates of RGCT. Indviduals may spend more energy competing for food and sheltering space (and avoiding harrassment from nonnatives) and less energy in reproduction, which may cause individuals to be more susceptible to predation or disease. 2) PREDATION. Results in death of individuals of smaller sizes.	1) **Highly confident** 2) **Highly confident**	Paroz 2005, p. 34 Shemai et al. 2007, pp. 315, 320, 321 Peterson et al. 2004, pp. 768, 769

THEME: Nonnative Competing Trout			
[ESA Factor(s): C,E]	**Analysis**	**Confidence / Uncertainty**	**Supporting Information**
POPULATION & SPECIES RESPONSES			
Effects of Stressors: - POPULATIONS [RESILIENCY]	1) COMPETITION. Decreased fitness results in lower reproductive success and lower population growth rates. When brook and brown trout invade streams occupied by cutthroat trout, the native cutthroat trout decline or are displaced. Cutthroat trout condition declines in the presence of brook and brown trout. Age-0 cutthroat trout survival is 13 times higher when brook trout are removed, and age-1 survival is twice as high. 2) PREDATION. Higher mortality rates and lower recruitment of RGCT leads to overall decrease in population size by removing smaller individuals and preventing recruitment from subadults to reproductive adults. It is unknown how quickly populations are affected after nonnative competing trout are introduced; it may take years (or decades) for RGCT populations to be affected, and longer for extirpation to occur, or it could happen more quickly.	**1) Highly confident** **2) Moderately confident** about effects of predation on RGCT. **Low confidence** in how quickly populations are affected.	Peterson et al. 2004, p. 761 Paroz 2005, p. 34 Shemai et al. 2007, pp. 315, 320, 321 Peterson et al. 2004, pp. 768, 769
- SCOPE	**Historic:** RGCT has been extirpated from about 90% of its historic range primarily due to stressors from nonnatives, resulting in the loss of RGCT populations; most of this range reduction was due to hybridizing nonnative trout. **Current:** Barriers and nonnative removals have reduced likelihood of further invasions. Currently 84 conservation populations have complete or partial fish migration barriers, eliminating or reducing risk of competing nonnative species invasion. See population resiliency analysis for geographic locations of RGCT populations related to nonnative trout. Cutthroat trout may occupy headwater streams and brook and brown trout occupy downstream reaches because of the influence of temperature on competitive abilities. Mechanical suppression of nonnative species is occurring on 10 streams by states of Colorado and New Mexico, as well as Vermejo Park Ranch. **Future:** Continued barrier construction and maintenance and nonnative suppression will reduce likelihood of further invasions. Brown trout may be able to move further upstream as stream temperatures become warmer, although we do not have any data supporting this to date. Brook trout may become less pervasive due to increased temperatures and winter flood frequency (cutthroat trout are less susceptible than brook trout.) See RGCT population model for assessment of risk to each population by competition and predation. The risk of nonnative competing trout invasion does not vary rangewide.	**Historic: Moderately confident** **Current: Highly confident** **Future: Highly confident** in rates of barrier construction and maintenance. **Moderately confident** in the effects warming temperatures and changing flood frequencies may have on nonnative trout.	Jager et al. 1999 pp. 232, 235 McCullough 1999, p. 156 IPCC 2002 p 32 Alves et al. 2008 p. 26 Peterson et al. 2008b Wenger et al. 2011a, pp. 1000-1001 Wenger et al. 2011b, pp. 14176 Kruse 2013, p. 4 RGCT Database RGCT status assessment model

THEME: Nonnative Competing Trout			
[ESA Factor(s): C,E]	**Analysis**	**Confidence / Uncertainty**	**Supporting Information**
Effects of Stressors: - SPECIES (Rangwide) [REDUNDANCY]	If future populations are lost due to nonnatives, then overall redundancy will continue to decline.	**Moderately confident**	
Effects of Stressors: - SPECIES (Rangwide) [REPRESENTATION]	Any future loss of populations will continue to reduce overall genetic and ecological diversity of the species, further limiting the subspecies' representation.	**Moderately confident**	
RISK OF EXTIRPATION 2023	Populations with **no nonnative trout** and with a **complete or partial barrier** to fish movement have no risk of extirpation by 2023 due to competition and predation. Populations **sympatric** with brown or brook trout with **no mechanical suppression** have a high risk of extirpation due to competition and predation. See Appendix C for projections of extirpation risk over longer time frames.		

THEME: Wildfire			
[ESA Factor(s): A,E]	**Analysis**	**Confidence / Uncertainty**	**Supporting Information**
SOURCE(S)	Wildfire frequency and intensity is increasing due to climate change (drier, warmer regional climate). Wildfire frequency is locally influenced by forest management.	**Highly confident** that fire is a natural, regular part of the ecosystem and that the incidence of large, hot fires has increased. **Moderately confident** that climate change will exacerbate the rate of burning even further.	Schoennagel et al. 2004 p. 666 Westerling et al. 2006 p. 941 Bachelet et al. 2007 IPCC 2007a (pg 15)
- Activity(ies)	Risk of wildfires can be affected by forest management activities; fire suppression and lack of thinning or prescribed burns can enhance conditions suitable for high-intensity wildfires.	**Highly confident** that management influences fire frequency and intensity	Ferrell 2002, pp. 11-12 Schoennagel et al. 2004 p. 669
STRESSOR(S)	When natural or human-caused catostrophic wildfires burn within watersheds upstream of RGCT populations, subsequent rainstorms produce ash and debris-laden runoff of water from the burned forest into streams occupied by RGCT. Stormwater runoff following wildfire results in highly sedimented and ash-laden waters and very unstable stream channels. Additionally, fire retardant is often dropped in wildfire areas, and those chemicals (such as surfactant foams and fire retardants) can cause fish mortality.	**Highly confident**	Rinne 1996 p. 654 Buhl and Hamilton 2000, pp 410-416 Brown et al. 2001 pp 140-141 Backer et al. 2004, pg 942, 943 USFS 2006 p. 32
- Affected Resource(s)	High quality water and stable stream channels.	**Highly confident**	
- Exposure of Stressor(s)	A wildfire event can happen at any time, but forest condition of some areas makes the probability of high-intensity wildfire greater. Wildfires may be patchy and burn hotter in some places than in others, allowing some portions of the population to survive and recolonize downstream reaches after ash flow effects have been ameliorated. The amount of ash flow from a fire depends on the severity of the fire, proximity to the stream habitat, stream channel morphology, timing, and amount of rainfall following the fire. The extent of one or more populations being affected depends on the location of the fire relative to the stream reaches occupied by RGCT.	**Highly confident**	Schoennagel et al. 2004, p. 669 Miller and Bassett 2013 Roberts et al. 2013 pg 6

THEME: Wildfire			
[ESA Factor(s): A,E]	**Analysis**	**Confidence / Uncertainty**	**Supporting Information**
- Immediacy of Stressor(s)	**Historic:** Wildfires have resulted in at least 5 documented extirpations of RGCT populations in the past 10 years, with increasing fire severity in modern times due to forest management practices. **Current:** Wildfires are contuing to occur. Several large fires have occured in recent years resulting in populations of RGCT being extirpated. **Future:** Climate change is predicted to cause southwestern forests to be hotter and drier in coming decades, resulting in higher risks of catostrophic fires. Land managers are making efforts to reduce fire risks. Fish managers are committed to respond with restoration activities following wildfires, which in some cases create opportunities for restoration when nonnative trout are eliminated from stream reaches historically occupied by RGCT.	**Historic: Highly confident** **Current: Highly confident** **Future: Moderately confident**	Schoennagel et al. 2004 p. 666 Westerling et al. 2006 p. 941 Bachelet et al. 2007 IPCC 2007a (pg 15) Extirpations: pers. comm. with B. Bakevich and J. Alves, 2014
Changes in Resource(s)	Ash-filled flood waters make stream habitat unhabitable and can kill all fish in the stream. Stream channel changes and water quality impacts can make streams unsuitable for years following the fire and flood event. Extent of the impact of a particular event depends on the local conditions and nature of the fire and flood relative to RGCT habitat. If a stream is sufficiently long, fish may survive in an unburned upstream reach or tributary, then recolonize the burned reach when habitat becomes suitable.	**Highly confident**	Rinne 1996 p. 655 Brown et al. 2001 pp. 140-141
Response to Stressors: **- INDIVIDUALS**	All life stages of RGCT in the reach exposed to significant ash flow are killed and elimnated.	**Highly confident**	Rinne 1996 p. 654
POPULATION & SPECIES RESPONSES			
Effects of Stressors: **- POPULATIONS [RESILIENCY]**	The RGCT population can be eliminated from the area impacted by the ash flow.	**Highly confident**	Rinne 1996 p. 654

THEME: Wildfire			
[ESA Factor(s): A,E]	**Analysis**	**Confidence / Uncertainty**	**Supporting Information**
- SCOPE	**Historic:** Wildfire is a part of the ecosystem in the southern Rocky Mountains. Wildfires have always occurred, and, historically, RGCT populations extirpated in one area would be eventually repatriated by nearby populations. **Current and Future:** The frequency and intensity of wildfire is increasing rangewide. As drought frequency increases due to climate change, dry forests will be more likely to burn and burn hotter than in the past. In the past 10 years, at least 5 populations have been extirpated due to the effects of wildfire, representing about 4% of existing populations. Any one stream has a low likelihood of experiencing wildfire during any single year. We expect wildfire to occur, although we are unable to predict the location. The networking of the stream system influences whether a population is extirpated or eventually repatriates the ash flow area; tributaries may provide refuges from ash flows where some portion of a population may survive (example: Polvadera Creek). TNC has provided a risk assessment of fire for RGCT. In general, populations in the Rio Grande Headwaters GMU have less risk of wildfire (categorized as moderate fire risk) than those in the rest of the range (categorized as high fire risk).	**Historic: Highly confident** **Future: Moderately confident**	Westerling et al. 2006, pp. 940-941 Miller and Bassett 2013 Roberts et al. 2013 p 6 Wuebbles et al. 2013, p. 16 RGCT database
Effects of Stressors: **- SPECIES (Rangwide) [REDUNDANCY]**	If future populations are lost due to wildfire, then overall redundancy will continue to decline. The number of populations experiencing wildfire is expected to increase due climate change, but this may be ameliorated if land managers can reduce forest fuels. In some cases, the population elimination resulting from ash flows can provide restoration opportunities where nonnative species had been sympatric with RGCT populations.	**Highly confident**	NMDGF 2013, p. 3
Effects of Stressors: **- SPECIES (Rangwide) [REPRESENTATION]**	Any future loss of populations can reduce overall genetic and ecological diversity of the species, further limiting the subspecies' representation, although this is dependent on the timing and location of fires and ash flows.	**Moderately confident**	

THEME: Wildfire			
[ESA Factor(s): A,E]	**Analysis**	**Confidence / Uncertainty**	**Supporting Information**
RISK OF EXTIRPATION 2023	Populations with a **moderate wildfire risk, long occupied stream lengths, and some stream connectivity** have a very low risk of extirpation due to the effects of wildfire by 2023. Populations with **high fire risk, short occupied stream lengths, and no stream connectivity** have a very high risk of extirpation due to the effects of wildfire by 2023. See Appendix C for projections of extirpation risk over longer time frames.		

THEME: Stream Drying			
[ESA Factor(s): A,E]	**Analysis**	**Confidence / Uncertainty**	**Supporting Information**
SOURCE(S)	Drought and, in some cases, water withdrawals	**Highly confident**	Pritchard and Cowley 2006, p. 36
- Activity(ies)	Streamflows may decline, particularly in summer, due to drought (reduced precipitation, snowmelt runoff, and groundwater recharge) in combination with hot summer temperatures, and also from instream and groundwater withdrawals. Drought, hot summer temperatures, and water withdrawals may become more severe due to climate change. Water withdrawals can occur from stream diversions (acequias) or groundwater pumping for agriculture or solar projects.	**Highly confident**	Nash and Gleick 1993 p. ix Barnett et al. 2008, p. 1082 IPCC 2007a p. 15 Ray et al. 2008 p. 37
STRESSOR(S)	Stream drying (the significant reduction or loss of streamflow) reduces or eliminates habitat available for all life stages of RGCT. Stream intermittency may cause water quality declines (increased temperature, decreased oxygen), lack of access to breeding, feeding, and sheltering areas, and stranding of fish.	**Highly confident**	Elliott 2000, pp 938, 945 Lake 2000, p. 577
- Affected Resource(s)	Aquatic habitat (providing breeding, feeding, and sheltering areas). Water with cool temperatures and high dissolved oxygen content.		
- Exposure of Stressor(s)	Stream drying typically occurs in the late spring or early summer timeframe, after snowmelt runoff but prior to summer monsoon rains. If monsoon rains fail to produce precipitation, the drying trend can extend into fall. Reproduction and recruitment may be reduced due to a lack of spawning habitat and habitat for eggs and young of year.	**Highly confident**	Elliott 2000

THEME: Stream Drying			
[ESA Factor(s): A,E]	**Analysis**	**Confidence / Uncertainty**	**Supporting Information**
- Immediacy of Stressor(s)	**Past:** This was not likely a significant ecological factor in the past, due to expanded range of the fish occuring in varying elevations. Under historic conditions, local drying of streams would have been short term and effects would have been offset by recolonization from nearby populations when the stream rewetted. **Current:** Stream drying has been shown to depress populations, particularly after drought in 2002. However, in NM, virtually all populations remained stable through 2007 despite drought of early 2000s. In Colorado, the population in Medano Creek has survived 2 drought periods, although several other populations were either exirpated or populations reduced to low levels. **Future:** The stressor is expected to increase in frequency and intensity due to the effects of climate change making the region hotter and drier (and with earlier cessation of spring runoff).	**Past: Moderately confident** **Current: Somewhat confident** **Future: Highly confident**	Japhet et al. 2007, pg 42-44 Patten et al. 2007, p 13, 104 Isaak et al. 2012b, p. 548 Great Sand Dunes NP 2013, p. 1 Wuebbles et al. 2013, p. 16 RGCT database
Changes in Resource(s)	Habitat is reduced as shallow streams become intermittent or dry. Individuals must retreat into higher elevation, cooler steam reaches, springfed stream reaches, or lower elevation steam reaches with more pools (deeper water with lower temperatures). Pools in an intermittant section of stream will eventually reach higher temperatures during summer, potentially causing stress to individuals.	**Highly confident**	Elliott 2000, pp 938, 945 Lake 2000, p. 577
Response to Stressors: **- INDIVIDUALS**	**Adults:** More competition for scarce resources in available pools. Heat stress or death can occur. **Juveniles:** Heat stress. Higher mortality if in pools with adults, where predation may occur.	**Highly confident**	

THEME: Stream Drying			
[ESA Factor(s): A,E]	**Analysis**	**Confidence / Uncertainty**	**Supporting Information**
POPULATION & SPECIES RESPONSES			
Effects of Stressors: - POPULATIONS [RESILIENCY]	Demographic: Loss of individuals results in reduction of population sizes. If drought persists for only 1-2 years and sufficient refugia exist, the population can likely rebound. If drought is longer and/or there is a lack of refugia, extirpation of the population is likely. Historically, drought has occurred and streams have dried, but populations were able to be recolonized from other reaches. Recently, North Fork Carnero Creek, in Colorado, appears to have been extirpated after the drought of 2011 and 2012. We don't have any examples where streams have been affected only by water withdrawal, but this may be an exarcerbating factor.	**Highly confident**	RGCT Database J. Alves, pers. comm.
- SCOPE	Stream drying from drought can affect streams throughout the range. Water withdrawals are localized by stream. Streams on the Rio Grande National Forest (Rio Grande Headwaters GMU) are afforded some protection from stream drying (from water withdrawals) via the water rights settlement agreement of 2000, in which water rights were reserved for instream flow. Streams in the southern extent of the subspecies' distribution (ie Caballo GMU, southern portion of Pecos GMU) are more vulnerable to stream drying as these streams tend to be in hotter and drier areas. Further, south-facing streams across the distribution and those with less riparian vegetation are more vulnerable than north-facing streams or those with shading riparian vegetation. Riparian management can decrease the vulnerability of a stream to drying. Summer streamflow has decreased rangewide by 5.3% per decade over the last 45 years, increasing the risk of stream drying. Frequency of drought is expected to increase due to climate change.	**Moderately confident**	Zeigler et al. 2012, pp. 1049-1050 Rio Grande Water Conservation District 2014, pp. 3-4 RGCT database

THEME: Stream Drying			
[ESA Factor(s): A,E]	**Analysis**	**Confidence / Uncertainty**	**Supporting Information**
Effects of Stressors: - SPECIES (Rangwide) [REDUNDANCY]	Losses of populations will reduce redundancy.	**Highly confident**	
Effects of Stressors: - SPECIES (Rangwide) [REPRESENTATION]	Any future loss of populations can reduce overall genetic and ecological diversity of the subspecies, further limiting the subspecies' representation.	**Highly confident**	
RISK OF EXTIRPATION 2023	Populations with **long occupied stream lengths, some stream networking within the occupied reach, and moderate to high baseflow discharges** have an extremely low risk of extirpation due to stream drying by 2023. Populations with **short occupied stream lengths, no stream networking, and very low baseflow discharges** have a low risk of extirpation due to stream drying by 2023. Although short stream lengths reduce the ability of the population to seek refuge and rebound after periods of drought, we have very few instances where populations were extirpated due to stream drying. (North Fork Carnero Creek appears to have been extirpated after the 2011-2012 drought; Medano Creek, which was thought to have been extirpated from drought (Japhet *et al.* 2007), was not extirpated, although numbers were quite low.) See Appendix C for projections of extirpation risk over longer time frames.		

THEME: Disease			
[ESA Factor(s): C]	**Analysis**	**Confidence / Uncertainty**	**Supporting Information**
SOURCE(S)	Whirling Disease: Caused by the nonnative myxosporean parasite *Myxobolus cerebralis*	**Highly confident**	DuBey et al. 2007, p. 1411
- Activity(ies)	**Historic:** Parasite introduced into US from Europe in 1950s. Disease transmitted by translocation of affected fish and worms. **Current/Future:** NMDGF policies and regulations prohibit the stocking of any whirling disease positive fish in the states of New Mexico. In Colorado stocking of whirling disease positive fish in protected habitats, which include native cutthroat trout waters, is prohibited. Testing for whirling disease involves collecting and sacrificing 60 fish (nonnatives are preferred over RGCT for testing, but some RGCT are usually collected)	**Highly confident**	Japhet et al. 2007, p. 12 Patten and Sloane 2007, p. 10 Nehring 2007, 2008
STRESSOR(S)	Parasites damage cartilage, killing young fish or causing infected fish to swim in an uncontrolled whirling motion, making it impossible to avoid predation or feed. Total year class failure can occur.	**Highly confident**	Koel et al. 2006
- Affected Resource(s)	Young-of-year and juvenile trout.		Nehring 2007, p. 1
- Exposure of Stressor(s)	Trout infected by eating the worms (*Tubifex tubifex*) carrying the parasite (specifically, the actinosporean triactionomyxons (TAMs) produced in gut of worms) or through contact with water in which TAMs are present. See population resiliency model for the assessment of disease risk for each population.	**Highly confident**	Koel et al. 2006 RGCT database RGCT status assessment model
- Immediacy of Stressor(s)	Whirling disease has affected Columbine Creek in NM and Placer Creek in CO in the past. No other known infections of RGCT populations.	**Moderately confident** that our knowledge of the incidence of whirling disease represents all of the affected streams.	Japhet et al. 2007, p 27 Patten and Sloane 2007, p. 5
Changes in Resource(s)	Infected fish die.	**Highly confident**	Hiner and Moffett 2001, p. 130 DuBey et al. 2007, p. 1411
Response to Stressors: **- INDIVIDUALS**	Infected fish die.	**Highly confident**	Hiner and Moffett 2001, p. 130 DuBey et al. 2007, p. 1411

THEME: Disease			
[ESA Factor(s): C]	**Analysis**	**Confidence / Uncertainty**	**Supporting Information**
POPULATION & SPECIES RESPONSES			
Effects of Stressors: - POPULATIONS [RESILIENCY]	Total year class failure can result from whirling disease infections. Within 4 months of exposure, 85% of population can die. Repeated year class loss can result in population loss. Whirling disease is the source of many major population declines of rainbow trout. To recover from whirling disease infection, all fish in the stream must be killed and the stream must remain fishless for three years.	**Highly confident**	Thompson et al. 1999, pp. 312-313 Nehring 2007, p. 2
- SCOPE	Whirling disease is found in NM and CO, but not in RGCT conservation populations at this time. 84% of the conservation populations are judged to have very limited risk from whirling disease or other potential diseases because the pathogens are not known to exist in the watershed or a barrier blocks upstream fish movement. 5% are at minimal risk because they are greater than 10 km (6.2 mi) from the pathogen or they are protected by a barrier, but the barrier may be at risk of failure. 7% were identified as being at moderate risk because whirling disease had been identified within 10 km of occupied habitat. No protection from being in high elevation headwater streams has been documented.	**Moderately confident** that our assessment of the risk of whirling disease is correct.	Nehring 2007, pg 10 Alves et al. 2008 RGCT database
Effects of Stressors: - SPECIES (Rangwide) [REDUNDANCY]	The loss of year classes will result in the loss of populations over time, which will result in a loss of redundancy. Populations known to have whirling disease are killed, left fishless for 3 years, and repatriated.	**Highly confident**	
Effects of Stressors: - SPECIES (Rangwide) [REPRESENTATION]	The loss of year classes will result in the loss of populations over time, which will result in a loss of representation. Populations known to have whirling disease are killed, left fishless for 3 years, and repatriated.	**Highly confident**	
RISK OF EXTIRPATION 2023	Populations identified as a **limited risk of infection** have no risk of extirpation due to disease by 2023. Populations identified as having a **moderate risk of infection** have a very low risk of extirpation due to disease by 2023. See Appendix C for projections of extirpation risk over longer time frames.		

THEME: Water Temperature			
[ESA Factor(s): A,E]	**Analysis**	**Confidence / Uncertainty**	**Supporting Information**
SOURCE(S)	Climate Change	**Highly confident**	IPCC 2007a,b
- Activity(ies)	Changes in air temperature and precipitation will likely lead to changes in water temperature	**Highly confident**	Poff et al. 2002, p. 4
STRESSOR(S)	Changes in air temperature and water temperature	**Highly confident**	Battin et al. 2007 Zeigler et al. 2012, pp. 1045-1046.
- Affected Resource(s)	Thermal suitability	**Highly confident**	
- Exposure of Stressor(s)	RGCT are exposed to the temperature and water changes wherever they occur.	**Highly confident**	
- Immediacy of Stressor(s)	**Past:** This was not likely a significant ecological factor in the past, due to expanded range of the fish occuring in varying elevations. Under historic conditions, streams with less than optimal water temperature conditions would have fewer RGCT until conditions improved, and effects would have been offset by recolonization from nearby populations. **Current/Future:** The stressor is expected to increase in frequency and intensity due to the effects of climate change making the region hotter and drier.	**Moderately confident**	Regonda et al. 2005, p. 373 Battin et al. 2007 Lenart et al. 2007, p 2 Barnett et al. 2008 Ray et al. 2008 p 1, 2,10 Clow 2010, p. 2297 Isaak et al. 2012b, p. 544 Llewellyn and Vaddey 2013, p. S-iv
Changes in Resource(s)	**Temperature:** Stream warming can cause some streams to become too warm for RGCT populations to thrive. Conversely, several streams that are currently colder than is optimal will warm and become more suitable.	**Moderately confident**	Rogers 2013 Zeigler et al. 2012 Zeigler et al. 2013a Zeigler et al. 2013b RGCT status assessment model
Response to Stressors: - INDIVIDUALS	Individuals in warmer than optimal water will be stressed, have lower fecundity, and could die if water is warm enough.	**Highly confident**	
POPULATION & SPECIES RESPONSES			
Effects of Stressors: - POPULATIONS [RESILIENCY]	Demographic: Loss of recruitment results in reduction of population sizes. If conditions persist for only 1-2 years and sufficient refugia exist, the population can likely rebound. If water temperatures increase by more than 2 degrees (currently expected), more streams than the few that are currently expected could become unsuitable.	**Moderately confident**	Roberts et al. 2013 Rogers 2013 Zeigler et al. 2013a Zeigler et al. 2013b

THEME: Water Temperature			
[ESA Factor(s): A,E]	**Analysis**	**Confidence / Uncertainty**	**Supporting Information**
- SCOPE	Temperature changes could occur rangewide, as climate change is expected to affect the southwest. However, streams in the southern extent of the subspecies' distribution (ie Caballo GMU, southern portion of Pecos GMU) are more vulnerable to temperature increases as these streams tend to be in hotter and drier areas. Further, south-facing streams across the distribution and those with less riparian vegetation are more vulnerable to temperature increases than north-facing streams or those with shading riparian vegetation. Riparian management can lessen temperature increases. Also, smaller streams are more affected by temperature changes than larger ones, which buffer temperature swings. Some temperature changes have been observed throughout the range of RGCT, including increased air temperatures of 0.29 degrees C per decade over the last 45 years.	**Moderately confident**	Smith and Lavis 1975, p. 229 Isaak et al. 2012a Isaak et al. 2012b, p. 544 Zeigler et al. 2012, pp. 1049-1050 Llewellyn and Vaddey 2013 Roberts et al. 2013 Zeigler et al. 2013b
Effects of Stressors: - SPECIES (Rangwide) [REDUNDANCY]	Loss of populations would result in a loss of redundancy.	**Highly confident**	
Effects of Stressors: - SPECIES (Rangwide) [REPRESENTATION]	Loss of populations would result in a loss of representation.	**Highly confident**	
RISK OF EXTIRPATION 2023	No populations throughout the range of Rio Grande cutthroat trout have currently been identified as having any risk of extirpation by 2023 due to water temperature effects. By 2040, those populations with **low risk** of chronic water temperature effects have no risk of extirpation due to the effects of increased water temperature. Those populations with **predicted acute effects** have a low risk of extirpation due to the effects of increased water temperature. See Appendix C for projections of extirpation risk over longer time frames.		

THEME: Changes in Flood Timing and Magnitude			
[ESA Factor(s): A,E]	**Analysis**	**Confidence / Uncertainty**	**Supporting Information**
SOURCE(S)	Climate Change	**Highly confident**	IPCC 2007a,b
- Activity(ies)	Changes in air temperature and precipitationwill likely lead to changes in the magnitude, timing, and duration of spring runoff floods and higher magnitude summer rainstorm floods.	**Highly confident**	Poff et al. 2002, p. 4 Barnett et al. 2008
STRESSOR(S)	Changes in timing and amount of floods	**Somewhat confident** that the change in flood timing and amount is a stressor to the subspecies.	Archer and Predick 2008, p. 23 Battin et al. 2007
- Affected Resource(s)	Water timing and amount		
- Exposure of Stressor(s)	RGCT are exposed to the changes wherever they occur. If hydrological changes result in different spring runoff, this is the time of year when the subspecies is preparing for spawning. Changes in summer floods are when eggs are in the gravel or when fry are emerging from the gravels.	**Moderately confident**	
- Immediacy of Stressor(s)	**Past:** This was not likely a significant ecological factor in the past, due to the large range of the subspecies occuring in varying elevations. Under historic conditions, streams with less than optimal flooding conditions would have fewer RGCT until conditions improved, and effects would have been offset by recolonization from nearby populations. **Current/Future:** The stressor is expected to increase in frequency and intensity due to the effects of climate change making the region hotter and drier (and with earlier cessation of spring runoff).	**Moderately confident**	Regonda et al. 2005, p. 373 Battin et al. 2007 Lenart et al. 2007, p 2 Barnett et al. 2008 Ray et al. 2008 p 1, 2,10 Clow 2010, p. 2297 Isaak et al. 2012b, p. 544 Llewellyn and Vaddey 2013, p. S-iv
Changes in Resource(s)	**Timing:** A change in timing or magnitude of floods can scour the streambed, destroy eggs, or displace recently emerged fry downstream. Change in the timing of runoff from spring to winter could disrupt spawning cues because peak flow would occur when the days are still short in length and water temperatures cold. Conversely, earlier spawning that may result from earlier floods may lead to a longer growing season for the fry, benefiting the subspecies.	**Low confidence** that a change in timing or magnitude of flooding will have a largely negative effect on RGCT populations.	Erman et al. 1988, pg 2199 Montgomery et al. 1999 Stewart et al. 2004, p. 1154 Stewart et al. 2005, p. 1137 Isaak et al. 2012b, p. 544 RGCT status assessment model
Response to Stressors: **- INDIVIDUALS**	Nests and eggs can be destroyed if flood changes cause scour after spawning. Some individuals may not reproduce if spawning cues are disrupted due to timing changes.	**Somewhat confident**	Erman et al. 1988, pg 2199 Montgomery et al. 1999

THEME: Changes in Flood Timing and Magnitude			
[ESA Factor(s): A,E]	**Analysis**	**Confidence / Uncertainty**	**Supporting Information**
POPULATION & SPECIES RESPONSES			
Effects of Stressors: - POPULATIONS [RESILIENCY]	Demographic: Loss of recruitment results in reduction of population sizes. If conditions persist for only 1-2 years and sufficient refugia exist, the population can likely rebound. If flood timing changes are dramatic and/or there is a lack of refugia, extirpation of the population is possible.	**Moderately confident**	Montgomery et al. 1999 Isaak et al. 2012b, p. 545 Roberts et al. 2013
- SCOPE	Hydrologic changes could occur rangewide, as climate change is expected to affect the Southwest. The seasonality of flows is projected to change. Anticipated changes include earlier snowmelt runoffs as well as increased variability in the magnitude, timing, and spatial distribution of streamflow and other hydrologic variables. Some hydrological changes have been observed throughout the range of RGCT, including increased air temperatures of 0.29 degrees C per decade over the last 45 years and snowmelt runoff occurring 10.6 days earlier than 45 years ago.	**Moderately confident**	Clow 2010, p. 2297 Isaak et al. 2012b, p. 544, 545 Llewellyn and Vaddey 2013, p. S-iv
Effects of Stressors: - SPECIES (Rangwide) [REDUNDANCY]	We do not expect an effect of changed hydrology on the subspecies' redundancy because of the uncertainty surrounding many of these relationships and how they may affect the subspecies. We expect that there may some negative effects (increased scouring) and some positive effects (longer growing season). We are uncertain about whether the net effect of these changes will be positive or negative.	**Moderately confident** that there will not be largely negative effects on subspecies' redundancy.	
Effects of Stressors: - SPECIES (Rangwide) [REPRESENTATION]	We do not expect an effect of changed hydrology on the subspecies' representation because of the uncertainty surrounding many of these relationships and how they may affect the subspecies. We expect that there may some negative effects (increased scouring) and some positive effects (longer growing season). We are uncertain about whether the net effect of these changes will be positive or negative.	**Moderately confident** that there will not be largely negative effects on subspecies' representation.	
RISK OF EXTIRPATION 2023	We have not identified any populations at risk of extirpation due to the effects of changed hydrology. Changed hydrology is too uncertain of a risk to the subspecies to add to the model as a risk factor.		

THEME: Land Management			
[ESA Factor(s): A]	**Analysis**	**Confidence / Uncertainty**	**Supporting Information**
SOURCE(S)	Land management actions	**Highly confident.**	
- Activity(ies)	Land management and uses. 1. Cattle Grazing. 2. Recreation (ie camping, hiking, ATV use). 3. Timber Harvest. 4. Road building. 5. Mining	**Highly confident.**	Behnke 1979, p 102 Alves et al. 2008
STRESSOR(S)	**1. Cattle Grazing:** Cattle grazing reduces riparian vegetation, increases sediment inputs, and alter hydrologic regimes. Land management that removes or degrades natural riparian or updland vegetation can impact the quality of water and stream channels in downstream reaches. This occurs through runoff of sediment or physical alteration of stream through stream bank erosion. Grazing within riparian areas can result in soil compaction, damage or elimination of plants, reduction in terrestrial insects (which fall into the water and are about half the trout diet), and changes in fluvial processes. Improper grazing can cause adverse impacts (e.g., loss of cover, increased sedimentation, loss of riparian vegetation) to some individual RGCT populations, especially during drought conditions when the cattle tend to concentrate in riparian areas. The effects of excessive grazing can also result in long-term impacts that change hydrology and soils, leading to downcutting or headcutting. **2. Recreation:** Heavy recreational use can result in damage such as reducing density of herbaceous plants, eliminating seedlings and younger trees, and increasing tree diseases. Additionally, recreation can increase sediment inputs to streams with road and trail construction. **3. Timber Harvest:** Logging affects riparian ecosystems through tree falling, log skidding, road construction, and direct removal of vegetation, all of which add sediment to streams. **4. Road building:** Road construction contributes significant sediment to streams as land is disturbed, and existing roads can collect add sediment to streams. Additionally, culverts and bridges constrict the channel, changing the channel morphology, leading to ponding upstream of the structure and erosion and bankcutting downstream. Culverts under roads may serve as migration barriers, which can be positive (preventing nonnative trout invasions) or negative (fragmenting RGCT habitat). **5. Mining:** Mining as well as sand and gravel operations can alter flow and sediment regimes.	**Highly confident.**	Behnke 1979 p 102 Armour et al. 1994, p. 10 Trimble and Mendel 1995 Fausch et al. 2006, p. 19 Saunders and Fausch 2007, p. 1224 Saunders and Fausch 2012, p. 1525 Poff et al. 2011, p. 2, 6

THEME: Land Management			
[ESA Factor(s): A]	**Analysis**	**Confidence / Uncertainty**	**Supporting Information**
- Affected Resource(s)	Aquatic habitat (providing breeding, feeding, and sheltering areas). Food availability is reduced when riparian area is overgrazed, resulting in a less heterogeneous riparian zone. Sediment-free gravels and cobbles on stream bottom are vital for producing aquatic insects for food and serving as spawning areas for egg incubation.	**Highly confident.**	Young et al. 2005, p 2400 Pritchard and Cowley 2006, p 25 Saunders and Fausch 2007, pp. 1221, 1224 Budy et al. 2012 p 437 Saunders and Fausch 2012, p. 1525
- Exposure of Stressor(s)	Land management changes that affect RGCT stream conditions, where they occur, would represent long-term changes in the stream conditions that could affect all life stages of RGCT.	**Low Confidence** that the stressors are actually exposured to RGCT populations.	
- Immediacy of Stressor(s)	Some land management activities have occurred in the past, present, and future. Past practices were likely more severe than current practices, due to implementation of best management practices and, for example, more restrictive travel management rules on Forest Service lands. Grazing has decreased overall in the last 20 years and has been better managed.	**Moderately confident.**	USFS 2005 Poff et al. 2011, p. 2
Changes in Resource(s)	Decrease in food availability and decrease in adequate spawning areas due to siltation in substrates.	**Moderately confident.**	Young et al. 2005, p 2400 Pritchard and Cowley 2006, p 25 Saunders and Fausch 2007, p. 1224 Budy et al. 2012 p 437 Saunders and Fausch 2012, p. 1525
Response to Stressors: **- INDIVIDUALS**	Reduced fitness of individuals if food supply is limited. Reduced survival of young and juvenile stages. Reduced reproductive success due to limited spawning areas.	**Moderately confident.**	
POPULATION & SPECIES RESPONSES			
Effects of Stressors: **- POPULATIONS [RESILIENCY]**	Possible reduced fitness, reduced survival, and reduced reproduction rates for affected populations. Reduced trout biomass when riparian area is overgrazed (resulting in less available terrestrial insects) Review of "habitat quality" of RGCT streams (Alves 2007, p. 20), found 56.8 % had good or excellent quality.	**Low Confidence** that land management activities are having significant population-level effects.	Alves et al. 2007 Saunders and Fausch 2007, p. 1224 Alves et al. 2008 Saunders and Fausch 2012, p. 1525

THEME: Land Management			
[ESA Factor(s): A]	**Analysis**	**Confidence / Uncertainty**	**Supporting Information**
- SCOPE	Land use activities occur at some level across the range of RGCT (percentages represent percent of occupied habitat experiencing these activities) (Alves 2008): 1. Grazing 87% 2. Recreation 90% 3. Timber harvest 19% 4. Roads 58% 5. Mining 3% The intensity of each activity as related to potential effects on RGCT habitat, individuals, and populations depends on the specific level of activities and the conditions at each site. Overall, land management practices have improved and have less direct impact on Rio Grande cutthroat trout streams, and some streams are still recovering from past land management practices. 1) GRAZING: Specific information on grazing impacts to Rio Grande cutthroat trout habitat on a rangewide basis is not available. We have no information that leads us to conclude that improper grazing is significantly affecting RGCT rangewide. 2) RECREATION: ATV use off of designated routes has been prohibited, reducing the impact of off road vehicles on the landscape. Camping and hiking have minimal effect on RGCT. 3) TIMBER HARVEST: Timber harvest in the National Forests has declined appreciably in the last 20 years. While the effects of past logging practices may still be evident on the landscape in some locations, we have no information to conclude that timber harvest is significantly affecting RGCT populations. 4) ROADS: Roads have been identified as an area of concern for some streams (e.g., Tio Grande, Rio Grande del Rancho). Culverts serve as migration barriers on certain streams but may also be fragmenting habitat in other locations. The USFS Travel Management Plan directs road building and includes guidance to minimize effects on aquatic resources. Although there have been some local effects of roads, they are not affecting the subspecies rangewide. 5) MINING: Occurs within 3% of RGCT streams. Not a significant factor.	**Moderately confident** that this represents the scope of land use activities.	USFS 2005 (70 FR 68264) Alves et al. 2008 Peterson et al. 2013b, p. 5

THEME: Land Management			
[ESA Factor(s): A]	Analysis	Confidence / Uncertainty	Supporting Information
Effects of Stressors: - SPECIES (Rangwide) [REDUNDANCY]	We do not expect an effect of land management on the subspecies' redundancy because of lack of response expected at the population level.	**Moderately confident**	Alves et al. 2008
Effects of Stressors: - SPECIES (Rangwide) [REPRESENTATION]	We do not expect an effect of land management on the subspecies' representation because of lack of response expected at the population level.	**Moderately confident.**	
RISK OF EXTIRPATION 2023	We have not identified any populations at risk of extirpation due to the effects of land management. Land management is not a high enough risk to the subspecies to analyze further.		

THEME: Angling			
[ESA Factor(s): B]	**Analysis**	**Confidence / Uncertainty**	**Supporting Information**
SOURCE(S)	Recreational Anglers		
- Activity(ies)	Fishing for RGCT.	**Highly confident**	
STRESSOR(S)	Mortality of those fish kept by anglers; occasional mortality of fish caught and released due to handling stress or damage from hooks.	**Highly confident**	Bartholomew and Bohnsack 2005, p. 140
- Affected Resource(s)	Individual fish die or may experience stress for a period of time.		
- Exposure of Stressor(s)	Those fish caught are exposed to the stressor. Those kept die. Those released may experience stress or occasionally death.	**Highly confident**	Bartholomew and Bohnsack 2005, p. 140
- Immediacy of Stressor(s)	**Past:** Angling for RGCT has occurred for at least a century, likley more. **Current/Future:** Angling is regulated by the state wildlife agencies. In NM, reduced bag limit of 2/day, in CO a bag limit of 4/day; some streams in both states are catch-and-release only. Special angling regulations occur on 85% of conservation populations. Fishing is likely to continue to occur at these same levels.	**Highly confident**	NMDGF 2002, p. 22 Alves et al. 2008, p. 47, 48
Changes in Resource(s)	Fish kept by anglers die. Fish released experience stress from handling and may die from injuries sustained, although this is expected to be rare.	**Highly confident**	Bartholomew and Bohnsack 2005, p. 140
Response to Stressors: **- INDIVIDUALS**	Individual fish die or may experience stress for a period of time.	**Highly confident**	Bartholomew and Bohnsack 2005, p. 140
POPULATION & SPECIES RESPONSES			
Effects of Stressors: **- POPULATIONS [RESILIENCY]**	Because conservation populations of RGCT are remote and RGCT are small, angling pressure on the populations is not expected to have a population-level effect.	**Highly confident**	Alves et al. 2008, p. 47
- SCOPE	Angling occurs in 84% of conservation populations. Many of the streams with pure populations of Rio Grande cutthroat trout are remote (*e.g.* populations in the upper Pecos GMU) and angling pressure is light.	**Highly confident**	Alves et al. 2008, p. 47
Effects of Stressors: **- SPECIES (Rangwide) [REDUNDANCY]**	Because no population-level effect of angling is expected, we do not expect there to be an effect on redundancy.	**Highly confident**	

THEME: Angling			
[ESA Factor(s): B]	**Analysis**	**Confidence / Uncertainty**	**Supporting Information**
Effects of Stressors: - SPECIES (Rangwide) [REPRESENTATION]	Because no population-level effect of angling is expected, we do not expect there to be an effect on representation.	**Highly confident**	
RISK OF EXTIRPATION 2023	We have not identified any populations at risk of extirpation due to the effects of angling.		

THEME: Management Actions			
[ESA Factor(s): E]	**Analysis**	Confidence / Uncertainty	Supporting Information
SOURCE(S)	Fisheries and land managers removing nonnatives, constructing and maintaining barriers, reintroducing RGCT, conducting riparian restoration, and improving habitat.	**Highly confident**	Conservation Strategy 2013 Conservation Agreement 2013
- Activity(ies)	**Nonnatives:** chemical removal, physical suppression, barrier construction and maintenance; **Riparian restoration:** restricting grazing, reducing roads and timber harvest in riparian area; **Habitat improvement:** reducing sediment inputs, improving pool ratio	**Highly confident**	Vermejo Park Ranch et al. 2013 Conservation Strategy 2013 Conservation Agreement 2013 Colorado Parks and Wildlife 2013 NMDGF 2013
STRESSOR(S)	Reduces stressors related to nonnative species, stream drying, land management, and water temperature.	**Highly confident**	
- Affected Resource(s)	RGCT populations		
- Exposure of Stressor(s)	**Nonnatives:** reducing and eliminating nonnatives reduces their exposure to RGCT; **Riparian restoration** reduces exposure of RGCT to stream drying and water temperature changes; **Habitat improvement** reduces exposure of RGCT to stream drying and water temperature changes.	**Highly confident**	Vermejo Park Ranch et al. 2013 Conservation Strategy 2013 Conservation Agreement 2013 Colorado Parks and Wildlife 2013 NMDGF 2013
- Immediacy of Stressor(s)	N/A		
Changes in Resource(s)	Populations affected by management actions will remain stable or grow, as management actions reduce the stressors to the population (ie, nonnative trout removals, barrier maintenance, riparian management)	**Highly confident**	Vermejo Park Ranch et al. 2013 Conservation Strategy 2013
Response to Stressors: - INDIVIDUALS	Individuals will be exposed to fewer stressors, although the primary response will be at the population level.	**Highly confident**	Vermejo Park Ranch et al. 2013 Conservation Strategy 2013

THEME: Management Actions			
[ESA Factor(s): E]	**Analysis**	Confidence / Uncertainty	Supporting Information
POPULATION & SPECIES RESPONSES			
Effects of Stressors: - POPULATIONS [RESILIENCY]	Population resiliency will increase, and new populations with high resiliency will be added. Vermejo Park Ranch project expected to result in 20% increase in occupied stream miles for species, and likely to support a large interconnected population of over 75,000.	**Highly confident**	RGCT status assessment model Kruse 2013, p. 2 Vermejo Park Ranch et al. 2013
- SCOPE	Resiliency will likely increase wherever management actions occur	**Highly confident**	RGCT status assessment model
Effects of Stressors: - SPECIES (Rangwide) [REDUNDANCY]	The more reslient populations throughout RGCT range, the more redundancy will increase.	**Highly confident**	
Effects of Stressors: - SPECIES (Rangwide) [REPRESENTATION]	Representation will increase as populations are restored and rehabilitated.	**Highly confident**	
RISK OF EXTIRPATION 2023	We considered the management actions in the Vermejo Ranch CCAA and the CA/CS in future population projections. Additionally, we considered that, due to the importance of the species to both states, the states would continue to manage the species at some level as they have in the past. In future projections (past 2023) we examined both high and low levels of management to incorporate the range of management intensity that may occur. See Appendix C for specific information on how management was incorporated into our analysis.		

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APPENDIX C
RIO GRANDE CUTTHROAT TROUT
STATUS ASSESSMENT MODEL

Note: This is an appendix to the 2014 Rio Grande Cutthroat Trout Species Status Assessment Report. It provides only a summary of the methodology used in the Rio Grande Cutthroat Trout Status Assessment Model. The Model results are presented in Chapter 5 of the Report.

INTRODUCTION

As a part of the species status assessment (SSA) for the Rio Grande cutthroat trout, we conducted an analysis to quantitatively characterize the viability of the Rio Grande cutthroat trout. Our objectives were twofold: 1) to estimate the probability of persistence of each extant Rio Grande cutthroat trout population over time; and 2) describe the future persistence of Rio Grande cutthroat trout by forecasting the likely number of populations expected to survive[1] across the subspecies' range over time.

The purpose of this analysis is to quantitatively reflect our understanding of the future viability of this subspecies by using our professional judgment to apply the best available information to assess the status of the Rio Grande cutthroat trout. Like all models, ours is an oversimplification of the real world, and we do not claim that this analytical tool provides highly certain predictive outcomes. Instead it is designed to explicitly portray our understanding of how the status of the Rio Grande cutthroat trout may look in the future given our assumptions about the factors that we believe most influence the viability of the subspecies. The assignment of numerical values to reflect our best professional judgment of the risks to the subspecies provides an explicit way to communicate our understanding, but it does not mean the model is an overall objective assessment. To the contrary, it is a quantitative tool to show clearly the results of our subjective assessment of the future risks faced by the subspecies. This effort may represent a novel approach for the Fish and Wildlife Service in using this kind of numerical system to evaluate the status of a species by quantitatively forecasting the future resiliency, redundancy, and representation of the subspecies. This Appendix describes the analysis used in the accompanying Rio Grande Cutthroat Trout Species Status Assessment Report (SSA Report).

This analysis was conceived in large part based on the ongoing modeling work being conducted by a group of scientists using a Bayesian Network (BN) model to more comprehensively estimate the probability of persistence for Rio Grande cutthroat trout populations (funded by the State of Colorado). The effort was referenced in the 2013 Rio Grande cutthroat trout Conservation Strategy (p. 18). This new BN model for Rio Grande cutthroat trout is intended to provide both an assessment to measure population persistence and to provide a management planning tool for decisions about alternative future management actions. We had hoped to use the outcome from BN model in our status assessment for the Rio Grande cutthroat trout. However, the BN model was still under development at the time we needed to move forward in our analysis to support upcoming decisions related to the status of Rio Grande cutthroat trout (under the Endangered Species Act). We recognize that the work this group is doing is expected to be much more robust compared to our effort described here because it is planning to: 1) include many more factors; 2) incorporate the outputs of other modeling efforts; 3) use Bayesian statistics that allow for cumulative and synergistic relationships to be considered; and 4) include broader expert judgment input into the probability tables.

Nevertheless, to the extent possible, we attempted to incorporate many of the ideas and concepts from the ongoing BN modeling effort. Both efforts are intended to produce results that estimate the probability of

[1] For this report, the terms "persisting" and "surviving" are used interchangeably when referring to populations sustaining themselves beyond the end points evaluated.

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persistence of each Rio Grande cutthroat trout population in 2040 and 2080. Therefore, the outputs from our analysis should be directly comparable to the future output of the BN model. We appreciate that the authors developing the BN model shared preliminary descriptions with us so that we could craft much or our work in a similar fashion with consistent assumptions where possible. We also gained inspiration from the work of Roberts *et al.* (2013) where they used a simpler BN model to estimate probability of persistence for Colorado River cutthroat trout and from the unpublished work of Rogers (2013) who also used a simpler BN model to estimate probability of persistence for Rio Grande cutthroat trout. These examples were very helpful in our development of this analysis.

MODEL SUMMARY

This report documents the analysis that we undertook to quantitatively forecast the Rio Grande cutthroat trout's future condition in a way that addresses viability in terms of the resiliency, redundancy, and representation (Figure C1). As a consequence we developed two separate, but related, modules that:

1. Estimate the probability of persistence for each Rio Grande trout population by GMU for 3 time periods under a range of conditions; and
2. Estimate the number of surviving populations by GMU for 3 time periods under several scenarios.

For the first module, we used 7 risk factors to estimate the probability of persistence of each Rio Grande cutthroat trout population (Figure C1). For each risk factor, we used one or more population metrics that contribute to the risk of extirpation of the populations. We used our own expert judgment to develop risk functions for each population metric. These judgments were based on our understanding of these risk factors as explained in Appendix B and Chapter 4 of the draft SSA Report. We only considered the risk factors that we deemed are likely to have population level impacts based on our cause and effects analysis. For 4 of the risk factors, we accelerated the rate of risk increase over time because we believe that environmental changes associated with global climate change will likely increase the risks associated with those factors. We summed all the risk functions for each population and subtracted that sum from 1 to calculate a probability of persistence for each population[2]. We did this calculation for each population for future timeframes of 2023, 2040, and 2080. We also ran this model with and without suppression management activities for controlling competing nonnative trout at 10 populations where suppression is currently occurring. And we did the analysis under two conditions of moderate and severe effects of climate change. These forecasts resulted in a description of the resiliency of the populations in terms of probability of persistence of the current populations. By analyzing the resulting persistence probabilities by GMU, the results also provide a picture of representation and redundancy.

For the second module, we conducted a survival simulation based on the output of persistence probabilities from module 1 to forecast the number of populations that may survive over time (Figure C1). We used a randomization process to simulate whether a population remains extant or goes extinct based on our modeled probability of persistence. After running the simulation 100 times, we calculated an average number of surviving populations with a 95% confidence interval by GMU under variable conditions. To that simulated number of surviving populations we added an estimate of the number of populations that may be restored over time by proactive management. Forecasting future restoration efforts has a large amount of uncertainty beyond the next 10 years, so we used a range of possibilities to include in the model output. For the overall population survival model, we considered 9 possible scenarios including the 3 time intervals that produces a best case, worse case, and intermediate case projection. The results from this analysis provides an assessment of future redundancy and representation based on the number of forecasted surviving populations rangewide and an assessment of representation as we report the results by GMU over time.

We also calculated the potential number of stream kilometers that are forecasted to be occupied in the future using our future population simulation. We did this in order to compare the current and future status of the Rio

[2] If a population's probability of persistence fell below zero, then the population was given a zero for the remainder of the analysis.

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Grande cutthroat trout to the historical status in terms of total occupied habitat. This estimation is not very precise, however, because we had to make large assumptions[3] in estimating the future amount of occupied stream kilometers by population. Therefore, we only use these results as a general guide to compare the possible total occupied habitat in the future to historical and current levels.

For a description of the results of this analysis, please refer to Chapter 5 of the SSA Report.

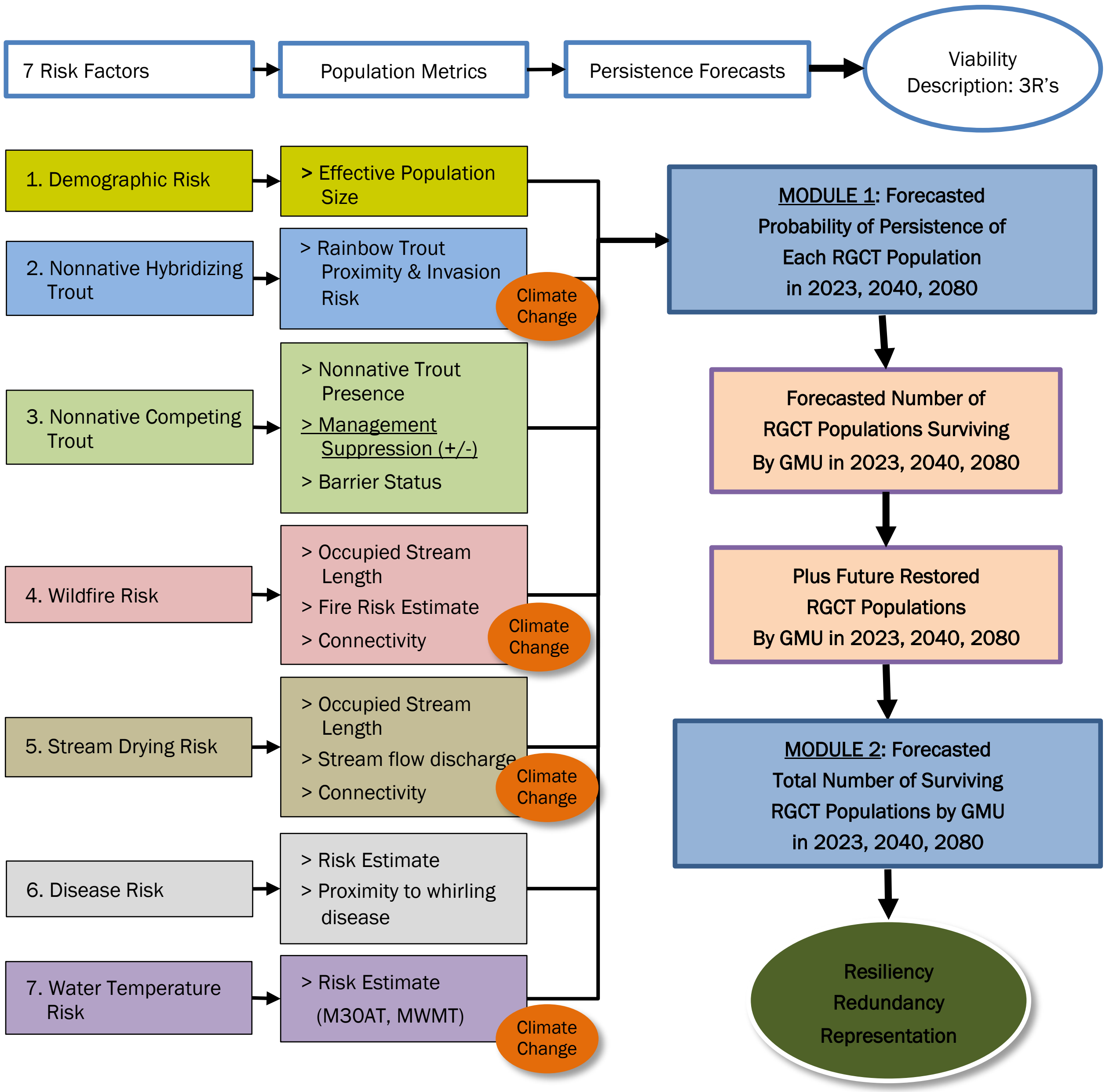

Figure C1. Conceptual diagram of Rio Grande cutthroat status assessment model.

[3] The assumptions were related to using average stream lengths for future persisting populations because the model does not predict which streams will be persisting in the future.

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INFORMATION SOURCES

We primarily used information from the Rio Grande cutthroat trout rangewide database (RGCT Database) from 2012, the most recent database available (see section 2.5, Management History of Rio Grande Cutthroat Trout, for more information about the database). We supplemented information from the RGCT Database based on new information received from various sources, included communications with Rio Grande cutthroat trout biologists from the states of Colorado and New Mexico. We also relied heavily on the prior work done for the most recent rangewide assessment for the Rio Grande cutthroat trout (Alves *et al.* 2008).

As a starting point, we used the 128 conservation populations [4] as tabulated from the RGCT Database by Rogers (2013, pp. 5—6, 18—21). These populations are from the database, with the exception that 6 of the Rio Grande cutthroat trout populations in the database were split into 2 populations to take into account the presence of a fish barrier that alters the condition of the populations upstream and downstream of the barrier. In some instances we consulted the Rio Grande cutthroat trout biologists to determine which conditions in the database applied to both upstream and downstream populations and which conditions were different between the 2 reaches. The 128 populations include these split populations. See Table C14 for a list of conservation populations evaluated in this analysis.

Six of the 128 populations that were in the initial version of the database we used were effectively removed from the analysis as they are presumed to be currently extirpated. Four of these populations (all from Lower Rio Grande GMU) were extirpated due to fire. One other population (also from the Lower Rio Grande GMU) was removed because after being separated into lower and upper segments based on the presence of a fish barrier, the lower segment does not contain Rio Grande cutthroat trout. One population (from the Canadian GMU) is not considered conservation population because it is currently more than 10% introgressed with rainbow trout genes. Our evaluation then used 122 as the number of extant conservation populations.

TIME FRAMES ANALYZED

We considered the current condition of the Rio Grande cutthroat trout as the status in 2013. We then forecasted the probability of persistence and survivability for Rio Grande cutthroat trout populations at three future time intervals: 2023, 2040, and 2080.

2013. This is considered the current condition of populations based when the Conservation Strategy was signed and one year from the latest data (2012) from the RGCT Database (see the discussion under Information Sources above). All the forecasting for future time intervals related to analysis of the risk factors and risk functions are largely based on the current conditions of the populations.

2023. This is approximately 10 years from current. This relatively short time period corresponds with the 10-year Rio Grande cutthroat trout Conservation Strategy to be implemented as part of the Rio Grande cutthroat trout Conservation Agreement signed in 2013. It also represents about two to three Rio Grande cutthroat trout generations (assuming generation time is between 3 and 5 years). Based on our understanding of recent environmental conditions and our ability to forecast over the next 10 years, we have high confidence (more than 90% sure) in our ability to forecast future conditions in 2023 related to the risk factors evaluated and to the responses of Rio Grande cutthroat trout populations.

[4] "Conservation populations" refers to populations of Rio Grande cutthroat that are less than 10% introgressed with nonnative trout genes. Throughout this document, references to populations of Rio Grande cutthroat trout refer to conservation populations.

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2040. This is approximately 25 years from current[5]. This time frame represents about five to eight Rio Grande cutthroat trout generations. We chose this time frame to correspond with available downscaled climate change models. Although we were not able to include climate change directly in our models, the BN model in development is planning to use climate change models and produce output of probability of persistence of Rio Grande cutthroat trout populations in 2040. We desired for the output from our model to be comparable to the developing BN model, and therefore, we used the same time intervals for our forecasting. This timeframe also represents a reasonable time from present when we have moderate confidence (70 to 90% sure) in our ability to forecast future environmental conditions related to the risk factors evaluated and to the responses of Rio Grande cutthroat trout populations.

2080. This is approximately 65 years from current. This time frame represents about 13 to 21 Rio Grande cutthroat trout generations. As with the 2040 time interval, this relatively long time frame of 65 years also corresponds with the output of downscaled climate change models and the developing BN model, so we chose 2080 for similar purposes as the 2040 time frame. It represents our outermost estimate for forecasting, where our confidence naturally decreases to somewhat confident (50 to 70% sure) in our ability to forecast future environmental conditions related to the risk factors evaluated and to the responses of Rio Grande cutthroat trout populations.

METHODS: POPULATION PERSISTENCE[6]

Risk Factors and Risk Functions

To accomplish our first objective to estimate the resiliency of current Rio Grande cutthroat trout populations, we developed a model to estimate the probability of persistence for each current population. After reviewing the causes and effects of factors that could have population-level effects to Rio Grande cutthroat trout, we chose seven risk factors to include in our analysis. For additional discussion of these factors, beyond the discussion here of how they were used in the analysis model, please refer to Chapter 4, Vulnerabilities, and Appendix B, Evaluating Causes and Effects for Rio Grande Cutthroat Trout Species Status Assessment, in the accompanying Draft SSA Report.

Seven Risk Factors

1. Demographic Risk
2. Hybridizing Nonnatives
3. Competing Nonnatives
4. Wildfire Risk
5. Stream Drying Risk
6. Disease Risk
7. Water Temperature Risk

For each risk factor (described in more detail below) we chose one or more Rio Grande cutthroat trout population metrics available to consider how that factor affects the risk of extirpation of Rio Grande cutthroat trout populations. For each state[7] of the population metric we assigned a risk function to that state for that risk factor (see Table C14 for a list of the population metrics used in this analysis). The first risk function for the 2023 forecast represented the probability (assigned as a number from 0 to 1) that that risk factor could result in the extirpation of a Rio Grande cutthroat trout population in that state (Table C1). The risk levels listed in Table C1 provide our valuation of the qualitative risk assessment we considered for each risk function and risk factor. We predicted these risk functions based on our best professional judgment as explained below under each risk function. To further

Key Uncertainty

Assigning risk functions is a fundamental assumption of this analysis. We cannot claim any particular level of accuracy related to the assignment of these risk functions. However, we are confident that the risk functions represent our best understanding of the risks to Rio Grande cutthroat trout related to the risk factors.

[5] We recognize that 2040 and 2080 are not exactly 25-year and 65-year forecasts from “current” (these dates are actually 27 and 67 years from 2013, which we are considering current), but it was more convenient to consider and calculate. We also realize that none of these forecasts are precise enough that +/- 2 years will make a substantial difference in the results in the model.

[6] All of the calculations and simulations for this model were conducted using Microsoft Excel 2010.

[7] “State” means the state of that metric, whether it is a category based on a natural scale, such as effective population size, or a condition such as Yes or No if competitive nonnative trout are present in the population.

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predict the risk functions for 2040 and 2080 time intervals, we scaled up the risk functions proportional to the length in the time interval. In other words, assuming we were considering 10-year, 25-year, and 65-year forecasts, we multiplied the 10-year risk function by 2.5 and 6.5 to determine the 2040 and 2080 risk functions, respectively (see below for explanation of increasing risks due to climate change). Because we had no information that the risks would change at a different rate over time, we increased the risks at a similar rate for all risk factors.

So, as a hypothetical example, for risk factor X (numbered 1 through 7) in state X.1 of the population metric, we might assign the risk function of 0.1, which means we predict that the population in that state has a 10% chance of extirpation by 2023 as a result of that risk factor. For this example, the 2040 risk function of risk factor X would be 0.25 in 2040 (a 25% chance of extirpation by 2040) and 0.65 in 2080 (a 65% chance of extirpation by 2080).

In assigning our risk functions we considered two components of risk: 1) the likelihood that the factor will actually occur over the given time frame; and, if it should occur, 2) the likelihood that the factor will result in the extirpation (as opposed to only some effects to individuals) of the population. We included both of these ideas in our judgments to assign risk functions. These risk functions reflect our perception about the potential impacts of these risks on the probability of persistence at the population scale.

Table C1. Categories of risk predictions used in the Rio Grande cutthroat trout status assessment model. Chance of extirpation is our predicted chance that a single population of Rio Grande cutthroat trout will become extirpated due to the effects of a given risk factor by 2023 (over about 10 years).

Risk Level by 2023	Risk Function	Chance of Extirpation
No risk	0.0	0%
Extremely low risk	0.001	0.1%
Very low risk	0.005	0.5%
Low risk	0.010	1.0%
Moderate risk	0.020	2.0%
High risk	0.100	10%
Very high risk	0.200	20%

Climate Change Considerations

One of the important factors to consider in the future status of Rio Grande cutthroat trout relates to the potential effects of climate change. Climate change represents a future source of environmental changes that can exacerbate a number of different stressors to Rio Grande cutthroat trout populations. Our assessment found that climate change is likely to influence four of the seven risk factors evaluated in this model (Figure C1): 2. Hybridizing Species Risk; 4. Wildfire Risk; 5. Stream Drying Risk; and 7. Water Temperature Risk. Figure C2 is an overview diagram of the conceptual relationships of the cause and effects pathway relating future climate change to potential impacts on populations of Rio Grande cutthroat trout.

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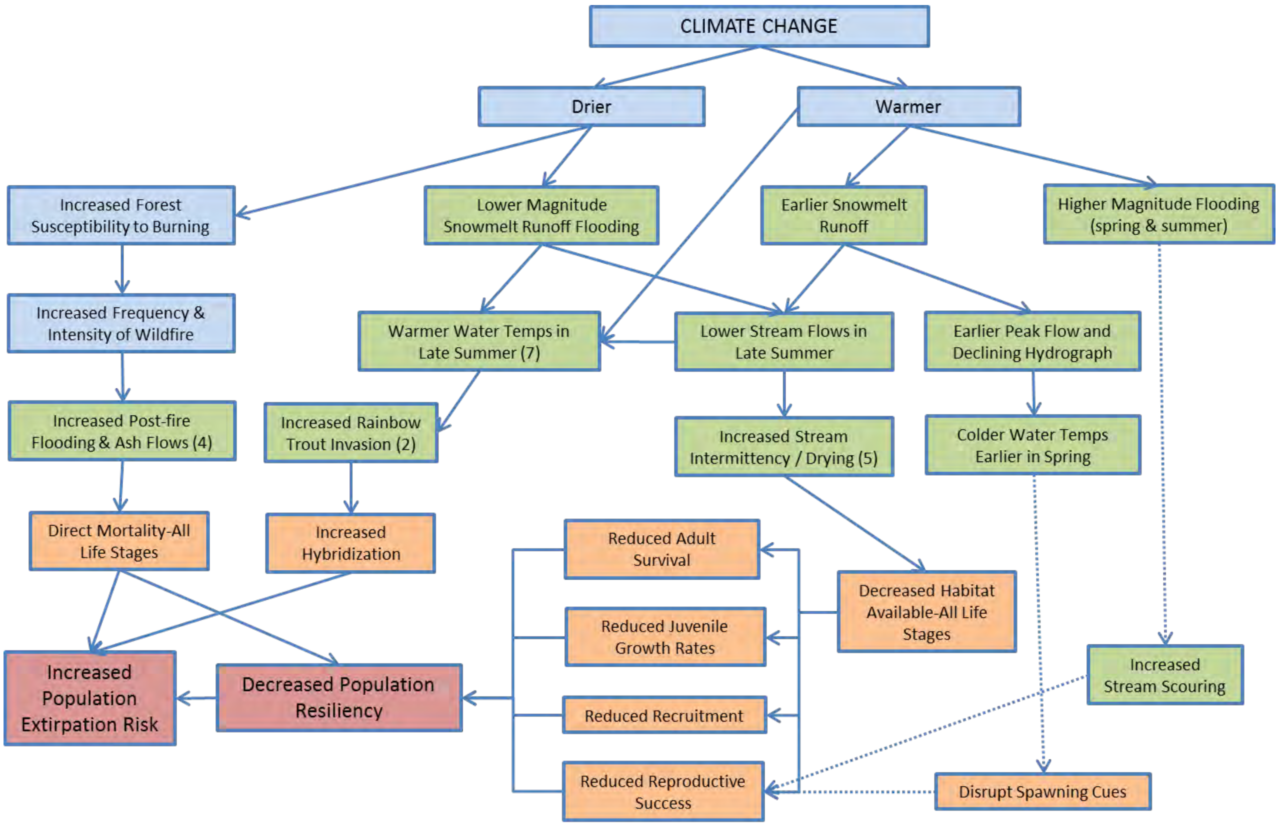

Figure C2. Diagram of conceptual relationships of climate change effects on Rio Grande cutthroat trout populations. Sources of effects are in blue; stressors are in green; responses by individuals are in orange; and population response is in red. Numbers in parentheses correspond to risk factors used in the status assessment model. Dashed lines indicate high uncertainty about the relationships and so those factors were not used in the status assessment model.

In addition to the four risk factors included in our analysis, we also considered two other potential stressors associated with possible hydrological changes that could be influenced by climate change. One is earlier peak spring snowmelt runoff flows and an earlier declining hydrograph. These changes could occur as a result of earlier warming temperatures in the spring, which could disrupt spawning cues and cause reduced reproductive success. Conversely, the longer growing season the fry may experience could also enhance juvenile survival through the following winter and increase recruitment success (this positive influence is not depicted in Figure C2). The other change is related to overall increase in flooding magnitude that could result from rain on snow events in the spring or increased large-scale flash flood events during the summer. These hydrological changes could result in increased stream scouring and alter stream habitats for the fish, particularly during spawning when eggs are in the gravel or fry have emerged; both are susceptible to being displaced and lost in flood events. In considering these two situations, we determined that the uncertainty of these relationships were too great to incorporate further into our analysis. Although these effects are possible, with our current level of understanding we could not adequately account for how these changes might result in specific population-level effects to the Rio Grande cutthroat trout, therefore we did not include these risk factors in the status assessment model.

We can conceptually understand that a warming climate can exacerbate four of these stressors; however, the magnitude of the increase in these stressors due to climate change is difficult to project and quantify. Therefore, to address this uncertainty we considered two different levels of climate change influence in our model. We incorporated these influences by changing the rate of increase in risk over time for those risk factors identified to be influenced by climate change (Table C2).

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In calculating the probability of persistence of Rio Grande cutthroat trout populations over time we used three different multipliers to scale the risk from 2023 (a 10-year forecast) to 2040 (a 25-year forecast) and 2080 (a 65-year forecast). First, for those risk factors without a consideration for climate change (risk factors 1, 3, and 6), we assumed the risk would increase over time in a linear relationship proportional to the amount of time in the forecast. In other words, the 25-year risk function[8] (in 2040) is 2.5 higher than the 10-year risk function (25/10), and the 65-year risk function is 6.5 times higher than the 10-year risk function (65/10) (Table C2).

Dealing with Uncertainty

To address the uncertainty of climate change we ran the model with two climate change scenarios: one with a 5% and 10% increased risk in 2040 and 2080, respectively, and a second scenario with a 20% and 40% increased risk in 2040 and 2080, respectively.

However, for those risk factors that we believe are likely to be influenced by climate change (risk factors 2, 4, 5, and 7), we increased the risk over time such that the risk function increases more than the proportional time interval. To account for these increases in risk, we multiplied the risk functions used in the risk factors without climate change influences to reflect larger increases in risk of extirpation over time. We used our best professional judgment to estimate the multipliers that correspond with increasing risks. In addition, because of the high uncertainty associated with climate change we considered a “moderate” and a “severe” effect of climate change. For the moderate climate change effect, we increased the risk function over time by 5% for the 2040 forecast and 10% for the 2080 forecast (Table C2). The resulting moderate climate change 2040 multiplier was 2.625 ([25/10]*1.05), and the multiplier for 2080 was 7.15 ([65/10]*1.1). For the severe climate change effects, we increased the risk function over time by 20% for the 2040 forecast and 40% for the 2080 forecast (Table C2). The resulting severe climate change 2040 multiplier was 3.12 ([25/10]*1.2), and the multiplier for 2080 was 9.1 ([65/10]*1.4). These multipliers were our best judgment of the potential effects of climate change on the risk factors, and using two multipliers provided us the opportunity to view the model results under two different climate change scenarios.

Table C2. Multipliers used to scale risk functions over time from the 2023 forecast to the 2040 and 2080 forecasts for Rio Grande cutthroat trout risk factors without climate change effects and with “moderate” and “severe” climate change effects.

	Risk Multiplier Over Time		
Risk Factors	**2023**	**2040**	**2080**
Not considered affected by climate change (Risk Factors 1,3,6)	1	2.500	6.500
Affected by climate change (Risk Factors 2,4,5,7):			
“Moderate” Effects (5% and 10% increase)	1	2.625	7.150
“Severe” Effects (20% and 40% increase)	1	3.120	9.100

[8] The discussion of the specific risk factors and risk functions are in the sections immediately following this discussion of climate change considerations.

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Risk Factors

The following descriptions explain the 7 different risk factors we analyzed, the metrics we included, and the risk functions that we assigned.

1. Demographic Risk

The risk factor associated with demographic effects is associated with the vulnerabilities related to small population sizes. We assume that small population sizes can lead to loss of genetic diversity and increased inbreeding depression, and the larger the population size the less likely deleterious genetic effects will be. These genetic effects increase the population's likelihood of extirpation from other risks. See Chapter 4 and Appendix B of the Draft SSA Report for discussion of the cause and effects of small population sizes on Rio Grande cutthroat trout.

Metric: Effective Population Size

We used an estimate of the effective population size for each Rio Grande cutthroat trout conservation population as the metric to determine the risks from small population sizes. The majority of the populations in the RGCT Database (101 of 127) had a reported density of Rio Grande cutthroat trout based on collected field data. The standard metric used in the database is an estimate of the number of adult fish (individuals greater than 120 mm TL (total length)) (Alves *et al.* 2008, p. 7) per mile of occupied stream length, usually estimated through three-pass depletion sampling. Although many populations have estimates over multiple sampling years, for our analysis we used the most recent survey data available. The year these estimates were made ranged by population from 2001 to 2012 (with one estimate from 1990). For these populations with density estimates, we multiplied the density of adult fish by the occupied stream length (see discussion of occupied stream length below) to reach a total estimate of adult fish for each population.

Some conservation populations are made up of multiple stream reaches identified in the RGCT Database with unique population density estimates. In these cases (5 populations) we used the estimate for each stream reach multiplied by that occupied stream length and then summed the products for each stream reach to generate a total number of fish for the population.

In some other cases there were no data available on the estimate of the number of fish in the population. For some of these populations, the database contained an estimate of the range of fish densities that were judged in the field to occur in those populations[9]. In these cases (7 populations), we used the midpoint of the density range as the density for those populations as the population estimate.

In a few other cases there was no data available for fish density, and there was also no density category included in the database. For these cases (14 populations) we used a calculation to estimate the total population size based on the occupied length of stream. This relationship was developed for other species of cutthroat trout by Young *et al.* (2005, p. 2404) and has been applied to Colorado River cutthroat trout modeling efforts (Roberts *et al*. 2013, p. 1388) and to Rio Grande cutthroat trout (Rogers 2013, p .5).

$$\sqrt{N_i} = 0.00508 \times (l_i + 5.148)$$

Where N_i is the census population size of cutthroat trout >75mm TL for population *i,* and l_i is the length of stream (meters) occupied by cutthroat trout.

The effective population size is an important metric to measure for assessing population persistence as it is considered a surrogate metric for genetic variation within a population. In general, the larger an effective population size the more genetic variation it should have. Low effective population sizes can result in loss of

[9] The categories of fish density estimates from the Rio Grande cutthroat trout database are in the following ranges (and the midpoint we used in our calculations of total population estimate): 0 to 50 fish (25); 50 to 150 fish (100); 150 to 400 fish (no populations missing in this category); >400 fish (no populations missing in this category).

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genetic diversity via genetic drift and inbreeding. To our knowledge, no populations of native trout have been extirpated due to demographic risk alone; instead, it is a factor that can make the population more vulnerable to extirpation from other factors.

To calculate the effective population size (Ne) as a proportion of the total population size of individuals greater than 120 mm TL (N), we used 0.25 as the N/N_e ratio.

$$N_e = N_i \times 0.25$$

Where N_e is the effective population size estimate, and N_i is the census population size of cutthroat trout population *i*.

Key Assumption

For those population calculated from stream lengths, we used an N/N_e ratio of 0.25 to estimate effective population size. For those populations estimated from census data, we used an N/Ne ratio of 0.375 to estimate effective population size.

One limitation of using this relationship for our model is that it was based on estimating population sizes that included all age-1 and greater fish that are equal to 75 mm TL or longer, while the Rio Grande cutthroat trout database uses 120 mm TL as the standard for adult fish. As a result, using the data from the Rio Grande cutthroat trout database requires an adjusted N/Ne ratio to account for the fish in the 75-120 mm TL range. There is some debate in the literature about the appropriate ratio to apply; we followed the rationale used by Roberts *et al.* (2013, p. 1388) to use 0.25. However, we recognize that Roberts was assuming N was a measure of all individuals greater than 75 mm TL, rather than 120 mm TL. After analysis of Rio Grande cutthroat trout collection data in Colorado and New Mexico, Rogers (2014, pers. comm.) determined that 0.375 is the appropriate N/Ne ratio for census data in the RGCT database.

Risk Functions

Table C2 lists the risk functions we used for this risk factor. The larger the population, the lower the risk that a stochastic event associated with demographic risks will result in the extirpation of a population. We followed Roberts *et al.*’s (2013, p. 1387) method to use 500, 200, and 50 as states to predict potential genetic effects from small effective population sizes. At least 500 individuals were considered adequate to ensure long-term persistence, and less than 50 would be considered in danger of immediate inbreeding effects (Cowley 2007, p. 3). Populations between 50 and 200 are at risk of genetic consequences over the short term, and populations less than 500 but greater than 200 are at some risk over the long term. As long as populations are greater than 500, we do not expect demographic-related effects over any time interval (0% chance of demographic effects exacerbating other risk factors). Over the short term (to 2023) we would not expect any demographic risk for populations greater than 200. For populations less than 200 but greater than 50 we predict there is a low risk (1% over 10 years) of loss due to demographic effects exacerbating other risk factors. We predict a moderate risk (2% over 10 years) for populations less than 50.

The risk functions for demographic risk increase proportionally as the time interval lengthens (in other words the 2040 risk function is 2.5 times greater than the 2023 predicted risk, and the 2080 prediction is 6.5 times greater than the 2023 predicted risk) because we do not foresee any effects of climate change, or other sources, increasing the risk over time.

Table C3. States of population metrics and risk functions for demographic risks to Rio Grande cutthroat trout populations. Risks indicate the increased probability of extirpation from other risk factors.

		Predicted Risk of Extirpation		
	State of Population Metric	**2023**	**2040**	**2080**
1. Demographic Risk	1.1 Effective Population Size (N_e) > 500	0	0	0
	1.2 Effective Population Size (N_e) = 201 - 500	0	0.010	0.026
	1.3 Effective Population Size (N_e) = 50 - 200	0.010	0.025	0.065
	1.4 Effective Population Size (N_e) < 50	0.020	0.050	0.130

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2. Hybridizing Nonnative Trout

This risk factor associated with hybridizing nonnative trout describes the chance that a population will be extirpated or become hybridized at a level greater than 10%[10] over a given time frame. See Chapter 4 and Appendix B of the Draft SSA Report for discussion of the causes and effects related to hybridizing nonnative trout.

Metric: Proximity to Hybridizing Nonnative Trout

We evaluated the risk from hybridizing nonnative trout introduction as related to the proximity of hybridizing nonnative trout, mainly rainbow trout populations. The closer a population of (non-triploid) rainbow trout is to the Rio Grande cutthroat trout population, the greater the opportunity for either human-caused introduction or dispersal from a nearby stream. Additionally, those populations with secure stream barriers that prevent upstream fish dispersal have low risk of rainbow trout invasion.

Risk Functions (+Climate Change)

> **Key Assumption**
>
> For this model, we assumed the genetic status of untested populations was as presumed in the Rio Grande cutthroat trout database.

Table C3 lists the risk functions we used for this risk factor. We have assumed that populations identified in the Rio Grande cutthroat trout database as not tested but suspected to be unaltered (12 populations) actually are Rio Grande cutthroat trout conservation populations (less than 10% introgressed). For the purposes of this analysis, Rio Grande cutthroat trout populations greater than 10% introgressed are considered extirpated populations—there was one population in the database identified as greater than 10% introgressed. Populations identified in the Rio Grande cutthroat trout database as suspected hybridized (12 populations) were assumed hybridized and given a risk function of extirpation of 1 (already extirpated). Rio Grande cutthroat trout populations with less than 10% introgression of rainbow or other cutthroat trout genes are considered conservation populations of Rio Grande cutthroat trout.

The risk functions for the pure Rio Grande cutthroat trout populations were based on the presence of a secure stream barrier and whether the nearest wild rainbow trout population is located more or less than 10 km from the Rio Grande cutthroat trout population. This metric from the Rio Grande cutthroat trout database is consistent with that used by Alves *et al*. (2008, p. 35) to evaluate the risk of invasion by hybridizing nonnatives. For some populations, the Rio Grande cutthroat trout database identifies that there are no risks of hybridization. For those populations we used a 0% chance of extirpation by 2023, but we included a low risk (1% in 2040 and 2.6% in 2080 with no climate change multiplier) to account for the possibility of human-caused introduction. We assigned the risk of extirpation as very low (0.5% by 2023) for Rio Grande cutthroat trout populations where the nearest hybridizing nonnative trout population is greater than 10 km away. We believe this risk is very low because there are few examples of accidental introductions that are known. Rio Grande cutthroat trout populations located less than 10 km from hybridizing nonnative trout populations are at increased risk of extirpation, but still at a relatively low risk by 2023 (we predicted 1%, with moderate climate change effects), increasing proportionally in 2040 (2.6%) and 2080 (7.5%). Rio Grande cutthroat trout populations that are already invaded by rainbow trout (6 populations) but so far still persisting as conservation populations of Rio Grande cutthroat trout are considered at a very high risk of extirpation due to hybridization (10% in 2023 scaling up to 65% by 2080). We did not assign a 100% chance of extirpation by 2080 to sympatric populations because there are rare cases in which conditions for rainbow trout are not ideal, and Rio Grande cutthroat trout may continue to persist and not become introgressed more than 10%.

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[10] Rio Grande cutthroat trout populations with less than 10% genetic introgression are considered Rio Grande cutthroat trout conservation populations (Alves *et al.* 2008, p. 6). Rio Grande cutthroat trout populations with greater than 10% genetic introgression are not considered conservation populations.

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The risk functions for hybridizing nonnative trout increase proportionally as the time interval lengthens (in other words the 2040 risk function is 2.5 times greater than the 2023 predicted risk, and the 2080 prediction is 6.5 times greater than the 2023 predicted risk). We foresee that ongoing and future climate change could increase the risk of hybridization into the future because an expected drier, hotter climate could result in greater rainbow trout recruitment (Muhlfeld *et al.* 2014, p. 2). Therefore, we increased the rate of risk over time by 5% in 2040 and 10% in 2080 (for an predicte of moderate climate change effects, Table C4a) and by 20% in 2040 and 40% in 2080 (for an predicte of severe climate change effects, Table C4b). We used these two scenarios throughout the model to capture some of the uncertainty due to future climate change (see earlier discussion of Climate Change for more information).

Dealing with Uncertainty

How will climate change affect the risk of hybridization of Rio Grande cutthroat trout? To address this uncertainty we ran the model with moderate and severe levels of effects of climate change on the risk of invasion and hybridization by nonnative trout.

Table C4a. States of population metrics and risk functions for hybridizing nonnative trout risks to Rio Grande cutthroat trout populations under "moderate" climate change effects. Risks indicate the probability of an entire population being extirpated by hybridizing nonnative trout.

		Predicted Risk of Extirpation		
	State of Population Metric	**2023**	**2040**	**2080**
2a. Hybridizing Nonnative Trout (moderate climate change)	2a.1 <10% introgressed, or suspected unaltered, and no hybridization risk	0	0.010	0.026
	2a.2 <10% introgressed, or suspected unaltered, and > 10 km from rainbow trout	0.005	0.013	0.038
	2a.3 <10% introgressed, or suspected unaltered, and < 10 km from rainbow trout	0.010	0.026	0.075
	2a.4 Sympatric with rainbow trout	0.250	0.625	0.950
	2a.5 >10% introgressed or suspected hybridized	1	1	1

Table C4b. States of population metrics and risk functions for hybridizing nonnative trout risks to Rio Grande cutthroat trout populations under "severe" climate change effects. Risks indicate the probability of an entire population being extirpated by hybridizing nonnative trout.

		Predicted Risk of Extirpation		
	State of Population Metric	**2023**	**2040**	**2080**
2b. Hybridizing Nonnative Trout (severe climate change)	2b.1 <10% introgressed, or suspected unaltered, and no hybridization risk	0	0.010	0.026
	2b.2 <10% introgressed, or suspected unaltered, and > 10 km from rainbow trout	0.005	0.015	0.055
	2b.3 <10% introgressed, or suspected unaltered, and < 10 km from rainbow trout	0.010	0.030	0.109
	2b.4 Sympatric with rainbow trout	0.250	0.625	0.950
	2b.5 >10% introgressed or suspected hybridized	1	1	1

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3. Competing Nonnative Trout

This risk factor associated with competing nonnative trout describes the chance that a population will be extirpated over a given time frame as a result of the impacts associated with the presence of other nonnative trout, mainly brown and brook trout. While the majority of the impacts from nonnative trout (other than rainbow trout) comes from competition for space and resources, this risk factor also includes impacts from predation (particularly adult brown trout preying on young Rio Grande cutthroat trout). See Chapter 4 and Appendix B of the Draft SSA Report for discussion of the causes and effects related to competing nonnative trout. We considered three population metrics for this risk factor: presence of competing nonnative trout; management suppression; and barrier presence.

Metric: Presence of Competing Nonnative Trout

We evaluated this risk based on whether or not the competing nonnative trout are currently co-occurring with the Rio Grande cutthroat trout populations. Rio Grande cutthroat trout populations occurring with competing nonnative trout are at an increased risk of extirpation as a result. We used the information from the Rio Grande cutthroat trout database as to whether brown trout or brook trout are currently present. In some cases we supplemented this information with updated information from biologists familiar with the status of the populations. For five Rio Grande cutthroat trout populations in the database it was unknown whether competing nonnative trout are currently present. For these populations we assumed that the competing nonnative trout were not present.

> **Key Assumption**
>
> Where it was unknown if competing nonnative trout are co-occurring with 5 Rio Grande cutthroat trout populations, we assumed no competing nonnatives are present.

Metric: Management Suppression

A second metric we evaluated for those populations where competing nonnative trout are already present was the ongoing management suppression. For six Rio Grande cutthroat trout populations, fisheries managers are routinely (every few years) mechanically removing nonnative trout to suppress their populations temporarily (Alves *et al.* 2008, p. 48; RGCT Database). This suppression reduces the impacts on Rio Grande cutthroat trout populations and reduces their risk of extirpation. It is unknown whether these suppression activities will continue into the future. While it is likely that they may, at least for the 10-year duration of the Conservation Agreement, we chose to run our model with and without this suppression continuing. In this way we can weigh the benefits of these actions on the status of the Rio Grande cutthroat trout and evaluate this uncertainty in our model outputs. For the metric (described below) with suppression continuing, we assume that nonnatives will be mechanically removed on a regular basis through 2080 for those six populations where suppression is currently occurring.

> **Dealing with Uncertainty**
>
> Will current fisheries management activities continue to suppress nonnative trout? To address this uncertainty we ran the model with and without continued suppression actions.

Metric: Barrier Presence

Barriers to fish movement (either natural or man-made) are an important component for protecting Rio Grande cutthroat trout populations from invasion by nonnative trout and reducing their risk of extirpation (Alves *et al.* 2008, p. 5). The Rio Grande cutthroat trout database assesses the type of barrier present for each Rio Grande cutthroat trout population. We converted the information in the database to either a complete, partial, or no barrier reference for our metric (Table C5). We assumed that complete barriers are providing a high level of protection to prevent dispersal of nonnative trout upstream into a Rio Grande cutthroat trout conservation population. We assumed partial barriers were providing some limited protection from nonnative trout and populations with no barriers are not protected from nonnative trout.

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Table C5. Categorizing references of fish barriers in the Rio Grande cutthroat trout database into a barrier metric for the status assessment model.

Database Barrier Reference	Barrier Metric	Database Barrier Reference	Barrier Metric
Manmade temporary	Complete	Water diversion/partial	Partial
Temperature		Waterfall/partial	
Bedrock		Culvert/partial	
Water diversion		Manmade dam/unknown	
Insufficient flow		Water diversion/unknown	
Waterfall		Pollution/partial	
Manmade dam		Manmade temporary/partial	
Culvert		Unknown/partial	
Manmade complete			
Debris		None	None
		NA	

Risk Functions

Table C6 lists the risk functions we used for this risk factor. While impacts of co-occurring nonnatives do not necessarily result in extirpation of Rio Grande cutthroat trout populations in the near term, they do increase the risk of extirpation of over time. For populations where nonnative trout are already present and no mechanical suppression of the nonnative trout are occurring, we considered those populations to be at a relatively high risk of extirpation by 2023 (10% chance of extirpation, scaling up to 65% chance of extirpation by 2080). For populations where the nonnative trout are already present but suppression actions are occurring, we reduced the risk of extirpation to none by 2023 and to a moderate risk by 2040 (2% chance or extirpation, scaling up to a 5.2% chance by 2080). For populations without nonnative trout present and with a complete or partial barrier, we predicted there was no risk of extirpation by 2023 and a low and moderate risk for complete and partial barriers, respectively. For populations without nonnative trout present and with no barrier in place, we predicted a moderate risk of extirpation by 2023 (2% chance, scaling up to 13% chance of extirpation by 2080).

The risk functions for competing nonnative trout increase proportionally as the time interval lengthens. Brown trout may be able to range farther upstream than in the past (due to warming streams affected by climate change) (K. Fausch, CSU, pers. comm. 2014). Conversely, brook trout are expected to be negatively affected by climate warming and concurrent flow regime changes more than cutthroat trout (Wenger *et al.* 2011a, pp. 1000–1001; Wenger *et al.* 2011b, p. 14176). Because the effects of climate change may increase brown trout populations but decrease brook trout populations, we did not change the rate of increase associated with this risk factor due to climate change.

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Table C6. States of population metrics and risk functions for competing nonnative trout risks to Rio Grande cutthroat trout populations. Risks indicate the probability of an entire population being extirpated by competing nonnative trout.

		Predicted Risk of Extirpation		
	State of Population Metric	**2023**	**2040**	**2080**
3. Competing Nonnative Trout	3.1 Nonnatives present, no management suppression	0.100	0.250	0.650
	3.2 Nonnatives present, with continuing management suppression	0	0.020	0.052
	3.3 Not present, complete barrier	0	0.010	0.026
	3.4 Not present, partial barrier	0	0.020	0.052
	3.5 Not present, no barrier	0.020	0.050	0.130

4. Wildfire

This risk factor associated with wildfire describes the chance that a population will be extirpated over a given time frame as a result of the impacts associated with wildfire in the contributing watershed and the resulting floods and changes in the stream. Wildfire is an inherent risk to the persistence of Rio Grande cutthroat trout populations that has increased in recent times due to the relatively small and isolated nature of the currently remaining populations of Rio Grande cutthroat trout. See Chapter 4 and Appendix B of the Draft SSA Report for discussion of the causes and effects related to wildfire. We considered two population metrics for this risk factor: fire risk as estimated in The Nature Conservancy's (TNC) modeling effort on fire risk, and the occupied stream length.

Metric: Fire Risk

We predicted wildfire risk using the output from a newly developed model by TNC (Miller and Bassett 2013). It reviewed the watershed conditions contributing to each Rio Grande cutthroat trout conservation population. It characterized the impacts of wildfire for each population as moderate or high based on models evaluating fire behavior and debris flow. Their analysis is limited in application because it does not take into account the probability of fire occurrence in a given location. Factors affecting risk of ignition include location, fire return interval, snow pack, snow melt, average number of snow free days, slope, aspect, geographic orientation and average number of lightning strikes per year. Despite these limitations, this model provides a good indication of the risks of wildfire. The output of the model resulted in all the populations being at a "High" wildfire risk with the exception of 17 populations in the Rio Grande Headwaters GMU being at a "Moderate" risk.

Metric: Occupied Stream Length

We evaluated the potential impacts of wildfire risk based on the occupied stream length of the Rio Grande cutthroat trout populations. The longer an occupied stream length, the more likely that the population will survive a wildfire and debris flow event (Roberts *et al*. 2013, p. 1388) because it is more likely to have some stream reaches not affected by the fire, and it is more likely to have sufficient habitat diversity in the stream to provide refugia for individuals to survive (Isaak *et al.* 2012b, p. 551). We used four stream lengths to evaluate the effects of wildfire (Tables C7a and C7b). Streams longer than about 9.65 km (6 miles) are generally assumed to be long enough to encompass the habitat complexity necessary for the population to survive stochastic events (Hilderbrand and Kershner 2000, p. 515; Cowley 2007, p. 9). Streams between 9.65 km and 7.1 km are considered robust to stochastic risks (Roberts *et al*. 2013, p. 6), but may not have as much resiliency as longer streams. Streams shorter than 2.8 km (1.7 miles) are unlikely to have enough habitat variability for a population to be able to survive stochastic events (Harig and Fausch 2002, pp. 538–-539).

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Stream reaches smaller than 2.8 km may support populations of Rio Grande cutthroat trout, but local habitat quality is the greatest driver of population occurrence in short segments (Peterson *et al.* 2013, p. 10).

Metric: Stream Network

We also evaluated the potential impacts of wildfire risk based on the network (number of tributaries) of the streams occupied by Rio Grande cutthroat trout populations. Similar to overall stream length, the more networking an occupied stream has (in other words the more tributary branches in the stream), the more likely that the population will survive a wildfire and debris flow event. This is because these stochastic events are patchy in space or limited in extent, and networked streams are more likely to have some stream reaches not affected by the fire and are more likely to have sufficient habitat diversity in the stream to provide refugia for individuals to survive (Isaak *et al.* 2012b, p. 551; Roberts *et al*. 2013, p. 1388)). According to the RGCT Database, the vast majority of Rio Grande cutthroat populations has no stream tributaries and is categorized as isolated populations (109 of 122). Five streams are moderately networked (having 2 to 5 tributaries), and 11 streams are weakly networked (having 1 tributary) (Alves *et al.* 2008, p. 29). To account for the decreased risks from wildfire by streams with some connectivity, we reduced the risk functions for those streams. We used our best judgment of the benefits of networked streams to reduce the wildfire risk function of weakly connected streams by 25% and reduced moderately connected streams by 50%. This adjustment allows us to account for the benefits of connected streams that have a higher likelihood of surviving a wildfire event.

Risk Functions (+ Climate Change)

Tables C7a and C7b list the risk functions we used for this risk factor. We predicted that the risks for populations with moderate wildlife risk and long occupied stream lengths (>9.65 km) were at very low risk of extirpation due to wildfire by 2023 (0.5% chance of extirpation, scaling up to a 3.6% chance of loss by 2080). We chose 9.65 km (6 miles) as the threshold for the best stream length condition for several reasons. Hilderbrand and Kershner (2000, p. 515) estimated 8.3 km (5.1 mi) were required to maintain a population of 2,500 cutthroat trout when fish abundance was high (0.3 fish/m (0.09 fish/ft)). Adding a 10 percent loss rate to account for emigration and mortality increased the length up to 9.3 km (5.8 mi) in order to maintain 2,500 fish. Young *et al.* (2005, p. 2405) found that to maintain a population of 2,500 cutthroat trout, 8.8 km (5.5 mi) of stream were needed. Other studies have recommended stream lengths of 11 km (6.8 mi) and above (Cowley 2007, p. 10) based on stream widths. We chose stream lengths greater than 9.65 km (6 mi) to be the condition for best occupied stream lengths because this is a reasonable midpoint of those stream lengths recommended to support robust trout populations.

For the remaining conditions, we increased the risks by 25% for the next two states (moderate wildfire risk and 9.65 to 7.1 km stream length, and moderate wildfire risk and 7.1 to 2.8 km stream length) by 2023. For populations with a moderate fire risk and short occupied stream length (< 2.8 km) we predicted the risk to be low by 2023 (1% chance of extirpation, scaling up to 7.2% chance by 2080 with moderate climate change effects). For populations with high wildfire risk and long stream lengths (> 9.65 km), we predicted the fire risk to be low by 2023 (1% chance of extirpation, scaling up to 7.2 % chance with moderate climate change effects). We increased the risks by 100% for the next 2 states (high wildfire risk and 9.65 to 7.1 km stream length, and high wildfire risk and 7.1 to 2.8 km stream length) by 2023. For populations with a high fire risk and short occupied stream length (< 2.8 km) we predicted the risk to be low by 2023 (2% chance of extirpation, scaling up to 14.3% chance by 2080 with moderate climate change effects).

We foresee that ongoing and future climate change could increase the risk of wildfire impacts into the future because an expected drier, hotter climate would result in more frequent and larger intensity wildfires (Isaak *et al.* 2012b, p. 548). Therefore, we increased the rate of risk over time by 5% in 2040 and 10% in 2080 (for an estimate of moderate climate change effects, Table C7a) and by 20% in 2040 and 40% in 2080 (for an estimate of severe climate change effects, Table C7b).

Dealing with Uncertainty

How will climate change affect the risk of wildfire on Rio Grande cutthroat trout? To address this uncertainty we ran the model with moderate and severe levels of effects of climate change on the risk of wildfire.

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Table C7a. States of population metrics and risk functions for wildlife risks to Rio Grande cutthroat trout populations under "moderate" climate change effects. Moderate and high risks are from TNC's wildfire risk assessment and the stream lengths are the lengths occupied by Rio Grande cutthroat trout. Risks indicate the probability of an entire population being extirpated by the effects of wildfire. Risks were reduced by 25% for weakly networked streams and by 50% for moderately networked streams.

		Predicted Risk of Extirpation		
	State of Population Metric	**2023**	**2040**	**2080**
4a. Wildfire Risk (moderate climate change)	4a.1 Moderate Risk, stream length >9.65 km	0.005	0.013	0.036
	4a.2 Moderate Risk, stream length 9.65-7.1 km	0.006	0.016	0.045
	4a.3 Moderate Risk, stream length 7.1-2.8 km	0.008	0.021	0.056
	4a.4 Moderate Risk, stream length <2.8	0.010	0.026	0.072
	4a.5 High Risk, stream length >9.65 km	0.010	0.026	0.072
	4a.6 High Risk, stream length 9.65-7.1 km	0.013	0.033	0.089
	4a.7 High Risk, stream length 7.1-2.8 km	0.016	0.041	0.112
	4a.8 High Risk, stream length <2.8 km	0.020	0.053	0.143

Table C7b. States of population metrics and risk functions for wildfire risks to Rio Grande cutthroat trout populations under "severe" climate change effects. Moderate and high risks are from TNC's wildfire risk assessment and the stream lengths are the lengths occupied by Rio Grande cutthroat trout. Risks indicate the probability of an entire population being extirpated by the effects of wildfire. Risks were reduced by 25% for weakly networked streams and by 50% for moderately networked streams.

		Predicted Risk of Extirpation		
	State of Population Metric	**2023**	**2040**	**2080**
4b. Wildfire Risk (severe climate change)	4b.1 Moderate Risk, stream length >9.65 km	0.005	0.015	0.046
	4b.2 Moderate Risk, stream length 9.65-7.1 km	0.006	0.019	0.057
	4b.3 Moderate Risk, stream length 7.1-2.8 km	0.008	0.023	0.071
	4b.4 Moderate Risk, stream length <2.8	0.010	0.030	0.091
	4b.5 High Risk, stream length >9.65 km	0.010	0.030	0.091
	4b.6 High Risk, stream length 9.65-7.1 km	0.013	0.038	0.114
	4b.7 High Risk, stream length 7.1-2.8 km	0.016	0.047	0.142
	4b.8 High Risk, stream length <2.8 km	0.020	0.060	0.182

5. Stream Drying

This risk factor associated with stream drying describes the chance that a population will be extirpated over a given time frame as a result of the impacts associated with drought in the contributing watershed and the resulting loss in stream flow. Stream drying is an inherent risk to the persistence of Rio Grande cutthroat trout populations that has increased in recent times due to the relatively small and isolated nature of the currently remaining populations of Rio Grande cutthroat trout. See Chapter 4 and Appendix B of the Draft SSA Report for discussion of the causes and effects related to stream drying. We considered three population metrics for this risk factor: occupied stream length; stream discharge; and stream networking.

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Metric: Occupied Stream Length

We evaluated the potential impacts of stream drying based on the occupied stream length of the Rio Grande cutthroat trout populations. The longer an occupied stream length the more likely that the population will survive a stream drying event (Roberts *et al*. 2013, p. 1388) because it is more likely to have some stream reaches not affected by the loss of flow, and it is more likely to have sufficient habitat diversity in the stream to provide refugia for individuals to survive if some reaches become uninhabitable for some time period (Isaak *et al.* 2012b, p. 551). We used four stream lengths to evaluate the effects of stream drying (Tables C8a and C8b). Streams longer than about 9.65 km (6 miles) are generally assumed to be long enough to encompass the habitat complexity necessary for the population to survive stochastic events (Hilderbrand and Kershner 2000, p. 515; Cowley 2007, p. 9). Streams between 9.65 km and 7.1 km are considered robust to stochastic risks (Roberts *et al*. 2013, p. 6) but may not have as much resiliency as streams longer than 9.65 km (Hilderbrand and Kershner 2000, p. 515; Cowley 2007, p. 10). Streams shorter than 2.8 km are unlikely to have enough habitat variability for a population to be able to survive stochastic events (Harig and Fausch 2002, pp. 538–539).

Metric: Stream Discharge

We also evaluated the potential impacts of stream drying based on the predicted size of the stream as measured by stream discharge. The larger the discharge of streams during the summer and early fall critical time period, the less likely that stream will undergo substantial stream drying during drought events because it is more likely to maintain streamflow and habitat even when hydrological conditions decline. We used four stream discharge levels to evaluate the risks of stream drying (Tables C8a and C8b). The states for the stream discharge metric was based on the minimum 7-day average discharge between June 15 and September 30 (Zeigler *et al.* 2013b, p. 13). Streams predicted to have high discharge were those with a greater 0.1779 cubic meters per second (cms). Streams estimated to have moderate discharge were those with discharge ranging from 0.0291 to 0.1779 cms. Low discharge streams had discharges between 0.0017 to 0.0291 cms, and very low discharge streams had discharages less than 0.0017 cms.

Using data provided by Zeigler *et al.* (2013b, pp. 6–9), we were able to obtain discharge data for streams at 73 of 122 populations. For streams without data, we estimated the discharge based on the stream width as reported in RGCT database. Streams were categorized as less than 5 feet wide, 5 to 10 feet wide, 10 to 15 feet wide, and 15 to 20 feet wide (no streams were wider than 20 feet). We used an unpublished regression model to estimate discharge based on stream width which was derived from 267 field sites within the range of Rio Grande cutthroat trout (Zeigler, pers. comm. 2014). The resulting regression was: *ln(wetted width) = 2.453 + (0.383 * ln(discharge))*[11]. The results were that streams categorized as less than 5 feet wide in the RGCT Database were considered to have very low discharge, streams 5 to 10 feet wide were estimated to have low discharge, and streams between 10 and 20 feet wide were estimated to have moderate discharge.

Metric: Stream Network

We also evaluated the potential impacts of stream drying on the population based on the amount of networking (number of tributaries) of the streams occupied by Rio Grande cutthroat trout populations. Similar to overall stream length, the more networking an occupied stream has (in other words, the more tributary branches in the stream), the more likely that the population will survive a stream drying event (Dunham *et al.* 1997, p. 1130). This is because it is more likely to have some stream reaches not affected by the event, and it is more likely to have sufficient habitat diversity in the stream to provide refugia for individuals to survive (Isaak *et al.* 2012b, p. 551). According to the RGCT Database, the vast majority of Rio Grande cutthroat populations has no stream networking and is categorized as isolated populations (109 of 122). Four streams are moderately networked (having 2 to 5 tributaries), and nine streams are weakly networked (having 1 tributary) (Alves *et al.* 2008, p. 29). To account for the decreased risks from stream drying by streams with some connectivity, we reduced the risk functions for those streams. We used our best judgment of the benefits of

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[11] "Wetted width" is in meters and "discharge" is in cubic meters per second. The R^2 value of this regression was 0.44.

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networked streams to reduce the stream drying risk function of weakly connected streams by 25% and reduced moderately connected streams by 50%. This adjustment allows us to account for the benefits of connected streams that have a higher likelihood of surviving a stream drying event.

Risk Functions (+ Climate Change)

Tables C8a and C8b list the risk functions we used for this risk factor. Under moderate climate change conditions (Table C8a), we predicted that the risks for populations with large or moderate stream discharge, regardless of stream length, were at no risk of extirpation by 2023. Those populations in streams with moderate discharge we predicted to be at extremely low risk of extirpation by 2040 (0.1% chance of extirpation, scaling up to 0.29% chance of loss by 2080), regardless of stream length. Populations in low discharge streams and with long occupied stream lengths (>9.65 km) were predicted to be at extremely low risk of extirpation due to stream drying by 2023 (0.1% chance of extirpation, scaling up to a 0.7% chance of loss by 2080). For populations in low discharge streams and with 9.65 to 7.1 km occupied stream lengths we increased the risk to a 0.5% chance of extirpation due to stream drying by 2023 (scaling up to a 3.6% chance by 2080). For populations in low discharge streams and with 7.1 to 2.8 km occupied stream length we increased the risk to a 1% chance of extirpation due to stream drying by 2023 (scaling up to a 7.2% chance by 2080). And for the shortest streams (<2.8 km) with low discharge we predicted the risk as moderate for extirpation due to stream drying (2% chance of loss by 2023, scaling up to a 14.3% chance by 2080).

We foresee that ongoing and future climate change could increase the risk of stream drying into the future because an expected drier, hotter climate would result in more frequent and larger intensity droughts with decreased precipitation and increased evaporation and evapotranspiration (Archer and Predick 2008, p. 29; Isaak *et al.* 2012b, p. 549). Therefore, we increased the rate of risk over time by 5% in 2040 and 10% in 2080 (for an estimate of moderate climate change effects, Table C8a) and by 20% in 2040 and 40% in 2080 (for an estimate of severe climate change effects, Table C8b). In the same way we used two climate change scenarios to calculate wildfire risk and hybridization risk, we used these two scenarios to capture some of the uncertainty of stream drying risk due to future climate change (see earlier discussion in Climate Change section for more information).

Dealing with Uncertainty

To address uncertainty from climate change we ran the model with moderate and severe levels of effects of climate change on the risk of stream drying.

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Table C8a. States of population metrics and risk functions for stream drying risks to Rio Grande cutthroat trout populations under "moderate" climate change effects. Risks indicate the probability of an entire population being extirpated by stream drying. Risks were reduced by 25% for weakly networked streams and by 50% for moderately networked streams.

		Predicted Risk of Extirpation		
	State of Population Metric	**2023**	**2040**	**2080**
5a. Stream Drying Risks (<u>moderate</u> climate change)	5a.1 Any stream length, high discharge	0	0	0
	5a.2 Any stream length, moderate discharge	0	0.001	0.003
	5a.3 Stream length >9.65 km, low discharge	0.001	0.003	0.007
	5a.4 Stream length 9.65-7.1 km, low discharge	0.005	0.013	0.036
	5a.5 Stream length 7.1-2.8 km, low discharge	0.010	0.026	0.072
	5a.6 Stream length <2.8 km, low discharge	0.020	0.053	0.143
	5a.7 Stream length 9.65-7.1 km, very low discharge	0.002	0.005	0.014
	5a.8 Stream length 7.1-2.8 km, very low discharge	0.010	0.026	0.072
	5a.9 Stream length <2.8 km, very low discharge	0.020	0.053	0.143
	5a.10 Stream length <2.8 km, very low discharge	0.050	0.131	0.358

Table C8b. States of population metrics and risk functions for stream drying risks to Rio Grande cutthroat trout populations under "severe" climate change effects. Risks indicate the probability of an entire population being extirpated by stream drying. Risks were reduced by 25% for weakly networked streams and by 50% for moderately networked streams.

		Predicted Risk of Extirpation		
	State of Population Metric	**2023**	**2040**	**2080**
5b. Stream Drying Risks (<u>severe</u> climate change)	5b.1 Any stream length, high discharge	0	0	0
	5b.2 Any stream length, moderate discharge	0	0.001	0.004
	5b.3 Stream length >9.65 km, low discharge	0.001	0.003	0.009
	5b.4 Stream length 9.65-7.1 km, low discharge	0.005	0.015	0.046
	5b.5 Stream length 7.1-2.8 km, low discharge	0.010	0.030	0.091
	5b.6 Stream length <2.8 km, low discharge	0.020	0.060	0.182
	5b.7 Stream length 9.65-7.1 km, very low discharge	0.002	0.006	0.018
	5b.8 Stream length 7.1-2.8 km, very low discharge	0.010	0.030	0.091
	5b.9 Stream length <2.8 km, very low discharge	0.020	0.060	0.182
	5b.10 Stream length <2.8 km, very low discharge	0.050	0.150	0.455

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6. Disease Risk

This risk factor associated with disease describes the chance that a population will be extirpated over a given time frame as a result of the impacts associated with a future disease introduction, primarily whirling disease, but others as well. Although the risks of infection from whirling disease are relatively low for Rio Grande cutthroat trout populations, if a population is infected the risk of extirpation is high. See Chapter 4 and Appendix B of the Draft SSA Report for discussion of the causes and effects related to disease. We considered one population metric for this risk factor: the risk of infection, which is based on the distance of the Rio Grande cutthroat trout population to the nearest infection source.

Metric: Proximity to Infection Source

We evaluated the risk from disease as related to the proximity of disease causing pathogens to the Rio Grande cutthroat trout population. These metrics follow the rationale by Alves *et al.* (2008, p. 38). Populations where disease and pathogens are not known to exist in the watershed or a barrier provides complete protection to upstream fish movement are considered at limited risk of infection. Populations that have minimal risk are those with disease or pathogens in the watershed, but are more than 10 km away, or the barrier protecting the population may be at risk of failure. Populations at moderate risk are those where disease or pathogens have been identified within 10 km of the population.

Risk Functions

Table C9 lists the risk functions we used for this risk factor. We assumed that those populations with limited risk had no chance of infection by 2080. For populations identified at minimal risk of infection, we predicted the risk of extirpation as extremely low by 2023 (0.1% chance of extirpation, scaling up to a 0.65% chance by 2080). For populations identified at moderate risk of infection, we predicted the risk of extirpation as very low by 2023 (0.5% chance of extirpation, scaling up to a 3.25% chance in 2080). Populations already infected by disease are highly likely to be extirpated; there are no conservation populations considered currently infected.

The risk functions for disease increase proportionally as the time interval lengthens. We do not foresee any effects of climate change on the rate of increase associated with this risk factor.

Table C9. States of population metrics and risk functions for disease risks to Rio Grande cutthroat trout populations. Risks indicate the probability of an entire population being extirpated by disease.

		Predicted Risk of Extirpation		
	State of Population Metric	**2023**	**2040**	**2080**
6. Disease Risk	6.1 Limited risk	0	0	0
	6.2 Minimal risk	0.001	0.003	0.007
	6.3 Moderate risk	0.005	0.013	0.033
	6.4 Population is infected	0.8	0.9	0.95

7. Water Temperature Risk

This risk factor associated with increasing water temperatures describes the chance that a population will be extirpated over a given time frame as a result of the impacts associated with a future water temperature increase from a warming climate. These risks have been evaluated through field work monitoring seasonal stream temperatures (Zeigler *et al.* 2013b) and laboratory analysis to determine effects of increased water temperatures on individuals of Rio Grande cutthroat trout (Zeigler *et al.* 2013a). See Chapter 4 and Appendix B of the Draft SSA Report for discussion of the causes and effects related to disease. We considered one

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population metric for this risk factor: the risk of effects of increased water temperature, which is a combined risk analysis of expected increased water temperature.

Metric: Temperature Risk Analysis

We evaluated the risk from future water temperature rise using one metric that assesses the risk of water temperature increases on Rio Grande cutthroat trout populations. These metrics follow the rationale by Rogers (2013, pp. 4, 6, and 11). We used stream water temperature data from two sources, all of which are field monitoring data: one was published by Zeigler *et al.* (2013b) which had data for 48 streams; the second was unpublished data from an additional 23 streams (Zeigler *et al.* 2013c, unpublished data), as reported in Rogers (2013, pp. 18–21). The Zeigler *et al.* (2013b) data was reported as 2-hour maximum water temperatures (2-hr Max), which we converted to the mean weekly maximum temperature (MWMT) using the formula: MWMT=(0.9377 * 2-hr Max) + 0.0447, as suggested by Zeigler (2014, pers. comm.). The Zeigler *et al.* (2013b) data was also reported as mean weekly average temperatures (MWAT, maximum average temperature over a continuous 30 days of daily average temperatures), which we converted to the mean 30-day average temperature (M30AT) using the formula: M30AT=(0.9342 * MWAT) + 0.2622, as suggested by Zeigler (2014, pers. comm.). In all we had water temperature information for 71 of the 122 total populations.

The results of Zeigler *et al.* (2013a p. 1400) showed Rio Grande cutthroat trout juveniles in water greater than 25 degrees Celsius (°C) (under fluctuating temperature conditions similar to cooler nights and warmer days) could experience mortality due to water temperatures exceeding thermal tolerances. Zeigler *et al.* (2013a p. 1400) also showed that sublethal effects (such as decreased growth, malformations, and fungal growth) occurred at water temperatures above 18 °C. Therefore, we used these temperatures to evaluate the risks of streams having either "acute" (possible lethal effects) or "chronic" (possible sublethal effects) risks due to elevated water temperatures. In addition, to account for the potential effects of climate change to increase summer water temperatures, we followed the method of Rogers (2013, p. 9) and increased the reported temperatures (both MWMT and M30AT) for each stream by 2°C[12]. The results were that six populations where data were available had potential for acute effects (one of which also had potential chronic effects), and one population had potential for chronic effects. Populations with neither an acute nor a chronic risk of extirpation due to water temperature increases were considered at low risk. Because the vast majority of populations where data were available were found to be at low risk due to water temperature increases (7 out of 71 streams, 10%), we assumed that the populations not monitored for water temperatures were also at low risk[13] of extirpation from water temperature increases. Rogers (2013, pp. 9) made a similar assumption. This assumption would overestimate the probabilities of persistence in our analysis if other populations are actually going to be affected by increasing water temperatures.

Key Assumption

We assumed that the populations in streams not monitored for water temperature were at low risk of extirpation due to climate change.

Risk Functions (+ Climate Change)

Tables C10a and 10b list the risk functions we used for this risk factor. Under <u>moderate</u> climate change conditions (Table c10a), we predicted that the risks for populations identified as low risk for water temperature effects (including those not monitored) are at no risk of extirpation due to this risk factor by 2040 and at extremely low risk of extirpation by 2080 (0.1% chance of extirpation). For populations with predicted chronic effects on growth due to increasing water temperatures, we also predicted no risk of extirpation by 2040 and slightly higher risk of extirpation by 2080 (0.2% chance of extirpation). For populations with predicted acute

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[12] Although Rogers (2013, p. 9) did not include a reference for this application of a 2°C increase as a way to consider future effects of climate change, it is consistent with Robert *et al*. (2013, p. 1384) where they reference Ray *et al*. (2008, p. 29) that average summer air temperatures in the Southern Rocky Mountains are predicted to increase by ~2.7°C. So it is reasonable, as a rough estimate, to add 2°C to approximate climate change effects.

[13] Efforts are currently underway as part of the developing BN model for Rio Grande cutthroat trout to use actual down-scaled climate change models to predict water temperature changes at Rio Grande cutthroat trout populations, to include additional field data for stream temperatures, and to model the expected stream water temperatures for populations not monitored. Unfortunately this analysis has not yet been completed and was not available for use in our assessment.

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effects due to increasing water temperatures, we predicted no risk of extirpation by 2023 and a low risk of extirpation by 2040 (1% chance, scaling up to 2.86% chance of extirpation by 2080).

We foresee that ongoing and future climate change could increase the risk of extirpation due to water temperature increase into the future because an expected drier, hotter climate would result in increased water temperatures. Therefore, as we did with wildfire and stream drying risks, we increased risk over time by 5% in 2040 and 10% in 2080 (for an estimate of moderate climate change effects, Table C10a) and by 20% in 2040 and 40% in 2080 (for an estimate of severe climate change effects, Table C10b). In the same way we used these two scenarios to calculate nonnative hybridizing trout, wildfire, and stream drying risks, we used these two scenarios throughout the model to capture some of the uncertainty due to future climate change (see earlier discussion of Climate Change for more information).

Dealing with Uncertainty

To address uncertainty from climate change we ran the model with a moderate and a severe level of effects of climate change on the risk of water temperature increases.

Table C10a. States of population metrics and risk functions for water temperature rise risks to Rio Grande cutthroat trout populations under "moderate" climate change effects. Risks indicate the probability of an entire population being extirpated by water temperature.

		Predicted Risk of Extirpation		
	State of Population Metric	**2023**	**2040**	**2080**
10a. Water Temperature Risk (moderate climate change)	10a.1 Low Risk or Not Monitored	0	0	0.001
	10a.2 Chronic Effects on Growth Predicted	0	0.02	0.057
	10a.3 Acute Effects (lethal) Predicted	0	0.15	0.429

Table C10b. States of population metrics and risk functions for water temperature rise risks to Rio Grande cutthroat trout populations under "severe" climate change effects. Risks indicate the probability of an entire population being extirpated by water temperature.

		Predicted Risk of Extirpation		
	State of Population Metric	**2023**	**2040**	**2080**
10b. Water Temperature Risk (severe climate change)	10b.1 Low Risk or Not Monitored	0	0	0.001
	10b.2 Chronic Effects on Growth Predicted	0	0.02	0.073
	10b.3 Acute Effects (lethal) Predicted	0	0.15	0.546

Forecasting Persistence

Once we determined the risk functions for all of the risk factors being considered, we next calculated the probability of persistence for each current conservation population for each of our three time frames being considered. In this calculation we included two options related to competing nonnatives (with and without management suppression actions). We also included two different climate change scenarios (moderate and severe) which were included as alternative risk functions for four of the seven risk factors. This resulted in 10 different probabilities of persistence for each population (Figure C3).

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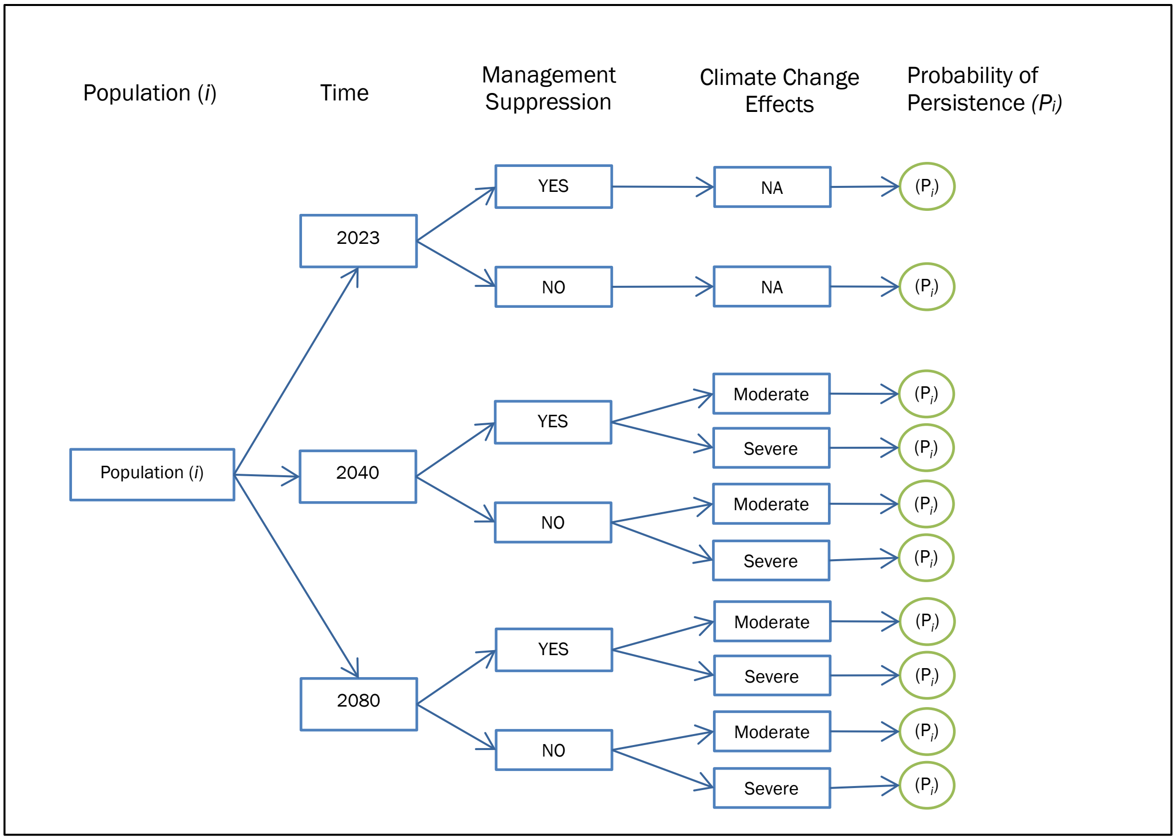

Figure C3. List of variable conditions for calculating probability of persistence for Rio Grande cutthroat trout populations.

For each of these 10 conditions we calculated an expected probability of persistence for each population by summing the individual risk functions for each risk factor and subtracting from 1. By summing the independent risk functions we can calculate a total risk of extirpation for each population that represents the cumulative chance of extirpation for each population for each scenario[14].

$$P_i = 1 - \sum R_{i,j}$$

Where P_i is the probability of persistence for population *i* and $R_{i,j}$ is risk factor *j* for population *i*. The risk factors are the probability of extirpation, and they are summed and subtracted from 1 to represent the probability that the population will persist (i.e., will not be extirpated). This approach assumes that in the absence of these ecological or environmental risk factors the probability of extinction is 0 (the probability of persistence is 1.0).

[14] Our model is not sufficiently sophisticated to take into account the potential for synergistic effects between the risk factors, which could occur in nature as multiple factors affect a species' viability. This is a recognized limitation in this approach. However, the cumulative nature of the approach and the linearly increasing risks over time provide a robust and conservative approach to assessing the viability of these populations.

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METHODS: POPULATION SURVIVAL

To estimate redundancy and representation of Rio Grande cutthroat trout we forecasted the number of populations that may persist in the future by simulating survival of the current populations and adding the number of populations projected to be restored over time. The sum of these two estimates resulted in a range of forecasted populations surviving under different conditions in each GMU for three time periods analyzed.

Population Survival Simulation

We constructed a survivability simulation model to estimate the number of RGCT populations that may be persisting in the future. To forecast the surviving populations, we used the results of the population persistence model and summed the probabilities of each population within each GMU and rangewide under each of the 10 conditions (Table C2). We then used a randomization process in MS Excel to simulate whether a specific population goes extinct under each of the 10 conditions. The simulation generates a random number (simulating a possible extirpation event) for a uniform distribution between 0 and 1.0. Then, if the randomly generated number is less than the persistence probability, the population remains extant (gets a value of 1) for the specified condition, if the random number is greater than the persistence probability, then the population goes extinct (gets a value of 0) for the specified condition. This model was developed as an *if* statement to mimic a binomial probability draw simulating population persistence.

$$T_{i,j} = \begin{cases} 1, if\ runif(0,1) < P_i \\ 0, if\ runif(0,1) > P_i \end{cases}$$

Where $T_{i,j}$ is a variable indicating whether trout population *i* in replicate *j* remains extant (1) or goes extinct (0). The persistence probability (P_i) derived from the risk functions serves as a threshold and allows us to convert the uniform random function into a binomial function of persistence estimate for each population. We ran the simulation 100 times for each population under each condition. We then calculated a mean number of populations surviving for each GMU and rangewide under each condition along with the 95% confidence interval around those estimates.

$$\overline{N_g} = \frac{\left(\sum T_{i,j,g}\right)}{100}$$

Where $\overline{N_a}$ is the average number of extant populations in GMU *g*, and *Ti,j,g* is the status of each population *i* (1= extant, 0 = extinct) in replicate *j*, in GMU *g*. The 95% C.I. was calculated as follows

$$95\%\ C.I. = \overline{N_g} \pm 1.96 \times S.D.(\overline{N_g})$$

Where S.D. is the standard deviation of the mean.

Restoration Forecasting

An important aspect of assessing the future status of the Rio Grande cutthroat trout is considering the future management actions that are likely to occur. State, Federal, Tribal, and private organizations have a number of past and ongoing activities both to protect, maintain, and enhance maintain current populations, but also to restore Rio Grande cutthroat trout to streams where they have been formerly extirpated. These population restoration efforts are a key component to the long-term viability of Rio Grande cutthroat trout.

Dealing with Uncertainty

To address uncertainty related to forecasting future population restorations, we estimated a range of the number of populations that may be restored in the future.

We incorporated a range of estimates ("High," "Low", and "Mid") of the potential numbers of populations that could be restored in the future into the population survival forecast. We assumed that those restored populations would be highly resilient (long stream lengths, large effective population sizes, and protected from nonnative trout). We based our estimates on the past and near future expectations for the number of

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populations that may be restored (Table C11). We generally took a conservative approach to estimating future population restorations past 2023.

For the 2023 population restoration forecast (Table C11), we used the number of populations planned to be restored by GMU from the 2013 Conservation Strategy. In that Strategy a range of populations are projected to be restored, which we used as the "High" (HE_{23}) and "Low" (LE_{23}) estimate for 2023, and we used the mean of the two for the "Mid" estimate.

For the 2040 population restoration forecast, the high estimate (HE_{40}) assumes that the high estimate from the 2023 forecast (HE_{23}) is completed and that future restorations continue at the same rate as the 2023 low estimate (LE_{23}) for the next 15 years [$HE_{40}=HE_{23}+(LE_{23}*1.5)$]. For the 2040 low estimate (LE_{40}) we used the 2023 low estimate for 2023 (LE_{23}), plus one additional population for each GMU [$LE_{40}= LE_{23}+1$]. The 2040 "Mid" estimate is an average of the 2040 low and high estimates.

For the 2080 population restoration forecast (Table C11), the high estimate (HE_{80}) is the sum of the 2023 high estimate plus the populations that would be restored at the same 2023 low estimate rate for the next 15 years plus additional populations restored at half of that rate over the next 40 years [$HE_{80}=HE_{23}+(LE_{23}*1.5)+(LE_{23}*2)$]. The 2080 low estimate is equivalent to the 2040 low estimate, which assumes no additional populations are restored for the 40 years between 2040 and 2080. The 2080 "Mid" estimate is an average of the 2080 low and high estimates.

Table C11. Estimates of the number of future populations of Rio Grande cutthroat trout restored by Geographic Management Unit. Totals for each time period are the cumulative totals.

	2023			2040			2080		
Populations per GMU	**High**	**Low**	**Mid**	**High**	**Low**	**Mid**	**High**	**Low**	**Mid**
Canadian	3	1	2	5	2	3	7	2	4
Rio Grande Headwaters	8	6	7	17	7	12	29	7	18
Lower Rio Grande	5	3	4	10	4	7	16	4	10
Caballo[15]	1	0	0	1	0	1	1	0	1
Pecos	3	1	2	5	2	3	7	2	4
Rangewide	**20**	**11**	**15**	**37**	**15**	**26**	**59**	**15**	**37**

Population Survival Scenarios

We used the various conditions, range of population survival simulations, and the ranges of possible population restorations to develop possible scenarios through which to forecast the range of total surviving Rio Grande cutthroat trout populations for the three time periods analyzed. We created 9 scenarios using different combinations of these conditions and results for each of the three time periods. Table C12 outlines these 9 scenarios.

For example, scenario 2 ("Worst Case with Severe CC, Low Mgt") includes the population simulation based on a severe estimate of climate change effects, low management (with no suppression of competing nonnative

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[15] We include Caballo GMU here because efforts are underway to restore a population in this GMU. However, we did not incorporate this population in the rest of the model output. See Chapter 3 of the SSA Report for a discussion of the Caballo GMU.

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trout), an estimate of the population simulation based on a negative 95% confidence interval of the mean, and a low estimate of populations being restored (from Table C11). This scenario represents the overall "worst case" scenario we considered.

On the other extreme, scenario 7 ("Best Case with Moderate CC, High Mgt") represents the overall "best case" scenario we considered. This scenario is based on moderate climate change effects, high management (with suppression of competing nonnative trout), an estimate of the population survival simulation with a positive 95% confidence interval of the mean, and a high estimate of populations being restored (from Table C11).

The results of both the population survival simulation and the forecasted number of populations restored are essentially a generated estimate of the number and distribution of Rio Grande cutthroat trout populations we predict will be surviving in the future. As such, we cannot predict exactly where these surviving populations might be, other than within the particular GMUs. We also cannot predict the actual condition (or resiliency) of these populations in the future. We presume that the surviving populations in the future would be in a range of conditions similar to those populations across the range today (expected to range from best to poor conditions).

Occupied Stream Length Forecasting

Dealing with Uncertainty

We recognize the high uncertainty in forecasting the future amount of occupied stream miles, due to the lack of confidence in forecasting the length of future populations. Therefore, we use the results only as a general measurement of the trend in relation to historic and current amounts of occupied habitat.

We also estimated the potential number of stream kilometers that are forecasted to be occupied in the future using our future population simulation. We did this in order to compare the current and future status of the Rio Grande cutthroat trout to the historical status in terms of total occupied habitat. We do not have a historical measure of the number of Rio Grande cutthroat trout populations that existed before modern impacts began to occur[16]. However, we do have estimates of historically occupied amount of stream kilometers (Alves *et al.* 2008, p. 13), the amount occupied in 2007 (Alves *et al.* 2008, p. 13), and an estimate of the current occupied stream miles from the Rio Grande cutthroat trout database. We estimated the future number of potential stream kilometers occupied based on our forecasted number of populations surviving. This estimation is not very precise, however, because we had to make large assumptions in estimating the future amount of occupied stream kilometers by population. For the population survival model we used an average occupied stream length (9.5 km) of currently occupied streams multiplied by the number of simulated streams surviving. For the estimate of restored populations we used a median stream length by GMU from an unpublished list of potential streams that could be restored[17]. We multiplied these stream lengths (ranging from 15 to 22 km) by the estimated number of streams to be restored. We summed the totals for the population survival simulation and populations restored to arrive at an estimate of future occupied stream kilometers. We have low confidence in the precision of these estimates because large assumptions[18] were made to approximate the average occupied stream lengths in the future. Therefore, we only use these results as a general guide to compare the possible total occupied habitat in the future to what was present historically and currently.

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[16] A measure of historical population numbers would not a reasonable assessment, given that many populations would have been large and interconnected compared to current populations.

[17] These lists were from the states of New Mexico and Colorado and were preliminary planning documents. We used the median rather than the mean stream length because some of the streams were extremely long and the likelihood of restoring the enter stream lengths seems low.

[18] We assumed future stream lengths would be equal to the average currently occupied stream lengths.

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Table C12. Range of scenarios used in forecasting survival of Rio Grande cutthroat trout populations.

	Scenarios	Climate Change	Nonnative Suppression	2023 Forecast Population Simulation	2023 Forecast Population Restoration	2040 Forecast Population Simulation	2040 Forecast Population Restoration	2080 Forecast Population Simulation	2080 Forecast Population Restoration
1	Best Case with Severe Climate Change and Low Management	Severe	No	Upper 95% C.I.	Mid	Upper 95% C.I.	Mid	Upper 95% C.I.	Mid
2	Worst Case with Severe Climate Change and Low Management			Lower 95% C.I.	Low	Lower 95% C.I.	Low	Lower 95% C.I.	Low
3	Intermediate Case with Severe Climate Change and Low Management			Mean	Low	Mean	Low	Mean	Low
4	Best Case with Moderate Climate Change and Low Management	Moderate	No	Upper 95% C.I.	Mid	Upper 95% C.I.	Mid	Upper 95% C.I.	Mid
5	Worst Case with Moderate Climate Change and Low Management			Lower 95% C.I.	Low	Lower 95% C.I.	Low	Lower 95% C.I.	Low
6	Intermediate Case with Moderate Climate Change and Low Management			Mean	Low	Mean	Low	Mean	Low
7	Best Case with Moderate Climate Change and High Management	Moderate	Yes	Upper 95% C.I.	High	Upper 95% C.I.	High	Upper 95% C.I.	High
8	Worst Case with Moderate Climate Change and High Management			Lower 95% C.I.	Mid	Lower 95% C.I.	Mid	Lower 95% C.I.	Mid
9	Intermediate Case with Moderate Climate Change and High Management			Mean	Mid	Mean	Mid	Mean	Mid

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RESULTS: POPULATION PERSISTENCE & POPULATION SURVIVAL

The results of our status assessment model will be used in the Rio Grande cutthroat species status assessment as a way to measure resiliency, redundancy, and representation. These measures allow us to describe the viability of the subspecies. Our results are displayed in *Chapter 5. Viability* of the SSA Report.

For a description of the results of this analysis, please refer to Chapter 5 of the SSA Report.

DISCUSSION

Model Strengths and Limitations

Like all models, this Status Assessment Model is only a quantitative reflection of our understanding of the way the ecological system works and influences the future status of the Rio Grande cutthroat trout. The analysis contains lots of uncertainty, assumptions, and professional judgment that affect the overall confidence of the results. However, this kind of forecasting is always fraught with uncertainties. We think it is worthwhile to be explicit about our understanding of the system in quantitative terms and be transparent about the uncertainties. The uncertainties in this kind of forecasting are inherently present whether we are explicit in quantitative terms or only describe the assessment in qualitative terms. The use of this kind of model is a somewhat novel approach to conducting status assessments and may or may not prove useful in future efforts to conduct species status assessments.

Risk Factors and Risk Functions

The most important part of this analysis is the quantification of the risk factors by assigning the risk functions to each state of the population metrics. These relationships form the foundation of the forecasts for the rest of the analysis. We used our best professional judgment to determine these risk functions, and, although subjective, they represent our understanding of the relationships between what the species currently has, in terms of the population metrics, and what the species is likely to have in the future as measured by the probability of extirpation. We explain these relationships elsewhere in the Draft SSA Report (Chapter 4 and Appendix B). As new information becomes available, or new, more robust models are conceived, these relationships are open to revision.

Cumulative and Synergistic Effects

Our approach to quantitatively assess the risks faced by Rio Grande cutthroat trout analyzes the cumulative effects of multiple risk factors in evaluating the viability of the species. By summing the risk functions for each population, we obtain a measure of the cumulative effects of all seven risk factors considered. However, the model is not sufficiently sophisticated to take into account the potential for synergistic effects and interactions between the risk factors, which undoubtedly could occur in nature as multiple factors affect a species' viability. This is a recognized limitation in this approach. However, the cumulative nature of the analysis and the linearly increasing risks over time provides a robust and conservative approach to assessing the viability of these populations.

Ongoing Management Actions

Ongoing and future management actions provide a critical contribution to the viability of the Rio Grande cutthroat trout. State, Federal, and Tribal agencies and private organizations are heavily engaged in the conservation of this subspecies, and these efforts provide substantial benefits to the subspecies. However, our modeling effort here could only directly incorporate limited aspects of this active management (suppression of competing nonnative trout and future restoration of populations). Because the species is so closely managed, some risks can be reduced by continued monitoring, maintenance of barriers, and other efforts to prevent nonnative trout invasions. For example, our risk functions assume that some passive management will continue into the future (for example, not stocking viable rainbow trout populations near Rio Grande cutthroat trout populations). These sorts of efforts are reflected in our risk functions for those factors

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that can be influenced by management. Nevertheless other management efforts, such as constructing new barriers, connecting existing populations, and responding to nonnative invasions, were beyond our ability to predict in the model, although we are confident they are likely to continue and will provide ongoing benefits to the Rio Grande cutthroat trout.

Key Assumptions and Uncertainty

Inherent in any effort to use a simple model like this one to reflect a complex ecological system are numerous assumptions about missing information and about how the system works. While we could not call out every assumption, throughout the model development we identified areas where key assumptions were made. In some cases, we had missing data and had to assume the population was in a particular state based on our best judgment considering the most likely state. In other instances, we made assumptions about the relationship between some important factors. Table C13 lists some of the key assumptions we made along with the possible effects of those assumptions on the model results.

Table C13. List of key assumptions. Effect of assumption on our model results is: "–" if the assumption is expected to result in a lower probability of persistence compared to an unknown reality; and "+" when the assumption is expected to result in a higher probability of persistence compared to an unknown reality; and "+/–" when the effect of the assumption on the model could be positive or negative.

Selected Key Assumptions	Number of Populations Affected	Effect of Assumption on Model Results
Effective population size, assumed N/Ne ratio of 0.375 for streams with population census data	108	+/–
Calculated population estimates using stream length formula	14	+
Populations with genetic status untested, assumed as presumed in database	24	+/–
Populations with unknown competing nonnatives present, assumed absent	5	+
Populations with no water temperature data, assumed no water temperature effects	57	+
Numbers of future populations restored, erred on low estimates	~11 - 59	–
Future occupied stream miles, assumed mean stream length for current and median stream length for future restored	All	+/–

Suppression of Competing Nonnative Trout

Suppression of competing of nonnative trout is an important management action that can help Rio Grande cutthroat trout populations continue to persistence even when the nonnative trout are present. Suppression activities (mechanically removing nonnatives) typically take place every few years and are currently occurring at 6 populations. One source of uncertainty was whether or not we should assume that this management action will continue for these populations into the future. To account for this uncertainty we ran the full analysis both with and without this suppression. The suppression activities make a large difference in our judgment about the risks of extirpation on each population where the suppression is occurring (Table C6). However, in relationship to all the population this distinction makes only a small difference in the overall outcome

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describing viability.   This is because the uncertainty only addresses 6 populations (out of a total of 122), and those populations may be facing other risks that lower their probability of persistence.

Climate Change

As described above under *METHODS: POPULATION PERSISTENCE, Climate Change Considerations* we conducted the analysis under two different conditions consider the possible effects of climate change. Overall, the difference between the moderate and severe conditions did not appear to be particularly large. This is likely because the risk factors we associated with climate change we judged to have relatively low risk functions on a single population basis, reflecting our understanding of the risk associated with the these factors. In addition our multiplying factor for risk functions with severe climate change effects of 20% and 40% still did not significantly increase the overall risks associated with these factors. We think that this is a fair representation of the effects of climate change, but future input on these factors, their risks, and the potential impacts of climate change could adjust these parameters.

Population Restoration

As described above under *METHODS: POPULATION SURVIVAL, Restoration Forecasting*, we used a range of estimates to accommodate for the uncertainty related to forecasting the number of populations that may be restored in the future. We think our methods predict a reasonable range of outcomes; however, these estimates have a substantial impact on the results of the total population survival estimates. In an attempt not to overestimate the potential for population restorations, we used some low estimates in our development of scenarios evaluated (Table C12). Had we used higher estimates in these scenarios, the results of the high estimates for population survival would have been considerably larger.

Forecasting

As discussed under Time Frames Analyzed above, there is an inverse relationship between the confidence we have in our results and the length of time for our forecasting. In many areas of our model there are large uncertainties related to our ability to forecast the future. Obviously any forecast, particularly those of ecological systems, is rife with uncertainties. We identified a number of these uncertainties and addressed them through calculating a range of possibilities so that our results reflect a range of outcomes. Obviously the confidence in our results decreases with increasing length of the forecast timeframe, which are reflected in our results where the ranges of outcomes increase between 2023, 2040, and 2080. We estimated our confidence level in the range of our results as high for the 2023 forecast (greater than 90% certain), moderate for the 2040 forecast (70 to 90% certain) and somewhat confident for the 2080 forecast (50 to 70% certain). We understand this is an inherent characteristic for forecasting any future events, particularly when related to complex ecological systems. We recognize this is a necessary shortcoming in our ability to forecast.

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Table C14. Summary data used in the Rio Grande cutthroat trout status assessment model: index to columns. More detailed explanations are provided in the report above. Most data is from the RGCT Database unless otherwise noted.

Column Header	Explanation
Conservation_Population	Names of the stream(s) or stream segment(s) included within the conservation population.
GMU	Geographic Management Unit.
CP_Pop_ID	Conservation Population Identifier. "L" designates the lower population for populations split into upper and lower stream segments because of a fish barrier.
EXTANT	Is the Rio Grande cutthroat trout population considered still extant?
Ne_Est	Effective population size estimate.
PopEst_Year	Year of the estimate of effective population size. "Est" indicates estimates based on the density category. "Calc" indicates estimates calculated using stream length. "na" indicates there was not a year associated with the population size estimate.
Genetic status	Genetic status of the population in terms of percent introgressed with rainbow trout. "NT-Sus_Un"= Not Tested – Suspected Unaltered. "NT-Sus_Hyb" = Not Tested – Suspected Hybridized.
RBT_Pres	Is rainbow trout present in the population?
Hyb_Risk	Estimated risk of hybridization based on proximity of rainbow trout.
Com_Nnat	Are competing nonnative fish present in the population?
Supp	Is suppression of competing nonnative fish occurring?
Barrier	Status of a fish barrier?
Str_Lth	Length of stream, in kilometers, occupied by Rio Grande cutthroat trout.
Networked	Level of stream network for the population.
Fire_Risk	Estimated fire risk from Miller and Bassett (2013).
Flow_Cat	Category of stream discharge.
Disease_Risk	Estimated risk of disease based on proximity to disease.
Temp_Risk	Estimated risk to water temperature increases (temperature data from Zeigler *et al.* 2013b and Zeigler *et al.* 2013c).

Table C14. Summary data used in the Rio Grande cutthroat trout status assessment model.

Conservation_Population	GMU	CP_Pop_ID	EXTANT	Ne_Est	Ne_Yr	Genetic status	RBT_Pres	Hyb_Risk	Com_Nnat	Supp	Barrier	Str_Lth	Networked	Fire_Risk	Flow_Cat	Disease_Risk	Temp_Risk
Ricardo, Elk, Gold, Leandro, Vermejo	Canadian	11080001cp001	YES	4,018	2006	Unaltered (< 1%)	NO	None	YES	YES	Complete	69.3	Weakly	High	Moderate	Limited	LowRisk
Little Vermejo Creek	Canadian	11080001cp002	YES	39	2003	Unaltered (< 1%)	NO	None	YES	NO	Complete	11.9	Isolated	High	Low	Limited	Acute
Leandro Creek	Canadian	11080001cp003	YES	126	2009	Unaltered (< 1%)	NO	None	YES	YES	Complete	3.1	Isolated	High	Low	Limited	LowRisk
McCrystal, North Ponil	Canadian	11080002cp001	YES	460	2009	Unaltered (< 1%)	NO	None	NO	NO	Complete	15.2	Isolated	High	Low	Limited	Acute
South Ponil Creek	Canadian	11080002cp002	YES	503	2009	Unaltered (< 1%)	NO	None	NO	NO	Complete	15.2	Isolated	High	Low	Limited	LowRisk
Middle Ponil Creek	Canadian	11080002cp003	**NO**	630	2004	>10% and <=20%	NO	<10km	NO	NO	Complete	9.6	Isolated	High	Low	Moderate	LowRisk
Clear Creek, Hdwtr Trib to Clear Creek	Canadian	11080002cp005	YES	337	2006	Unaltered (< 1%)	NO	None	NO	NO	Complete	7.5	Isolated	High	Low	Limited	LowRisk
East Fork Luna Creek	Canadian	11080004cp001	YES	394	calc	>1% and <=10%	NO	<10km	YES	NO	None	6.8	Isolated	High	Very Low	Limited	LowRisk
West Fork Luna Creek	Canadian	11080004cp002	YES	237	2004	Unaltered (< 1%)	NO	>10km	YES	NO	Partial	4.6	Isolated	High	Low	Limited	LowRisk
Rito Morphy, Hdwtr Trib to Rito Morphy	Canadian	11080004cp003	YES	158	est	Unaltered (< 1%)	NO	<10km	NO	NO	None	6.8	Weakly	High	Very Low	Limited	LowRisk
Santiago Creek	Canadian	11080004cp004	YES	154	est	>1% and <=10%	NO	>10km	NO	NO	None	6.6	Isolated	High	Very Low	Limited	LowRisk
West Alder Creek	RG Headwaters	13010001cp002	YES	89	2005	Unaltered (< 1%)	NO	None	YES	NO	Partial	7.2	Isolated	Moderate	Low	Limited	LowRisk
East Trib Middle Fk, West Trib, San Francisco Creek	RG Headwaters	13010002cp001	YES	1,432	2004	Unaltered (< 1%)	NO	None	YES	YES	Complete	25.3	Weakly	Moderate	Moderate	Moderate	LowRisk
Cat Creek	RG Headwaters	13010002cp002	YES	605	2007	Unaltered (< 1%)	NO	None	NO	NO	Complete	15.1	Isolated	Moderate	Very Low	Limited	LowRisk
Rhodes Gulch	RG Headwaters	13010002cp003	YES	236	2006	>1% and <=10%	NO	None	NO	NO	Complete	3.5	Isolated	High	Low	Limited	LowRisk
Torsido Creek	RG Headwaters	13010002cp004	YES	94	2005	NT-Sus_Un	NO	None	YES	NO	None	10.4	Isolated	High	Low	Limited	LowRisk
Jim Creek	RG Headwaters	13010002cp005	YES	480	2004	Unaltered (< 1%)	NO	None	YES	NO	None	10.2	Isolated	High	Low	Limited	LowRisk
Cuates Creek	RG Headwaters	13010002cp006	YES	141	2012	Unaltered (< 1%)	NO	None	NO	NO	Complete	6.1	Isolated	High	Low	Limited	LowRisk
Jaroso Creek	RG Headwaters	13010002cp007	YES	316	2012	Unaltered (< 1%)	NO	None	NO	NO	Complete	9.3	Isolated	High	Low	Limited	LowRisk
Jaroso Creek	RG Headwaters	13010002cp008	YES	739	2005	NT-Sus_Un	NO	None	YES	NO	Complete	6.2	Isolated	High	Moderate	Limited	LowRisk
Torcido Creek	RG Headwaters	13010002cp009	YES	1,054	2012	Unaltered (< 1%)	NO	None	NO	NO	Complete	13.2	Isolated	High	Low	Limited	LowRisk
Alamosito Creek	RG Headwaters	13010002cp010	YES	333	2005	Unaltered (< 1%)	NO	None	YES	YES	Complete	4.9	Isolated	High	Low	Limited	LowRisk
Vallejos Creek, North Vallejos	RG Headwaters	13010002cp011	YES	338	2005	Unaltered (< 1%)	NO	None	YES	NO	None	22.5	Isolated	High	High	Limited	LowRisk
Deep Canyon, South Fk Trinchera, Trinchera	RG Headwaters	13010002cp012	YES	92	2012	Unaltered (< 1%)	NO	None	YES	NO	None	18.9	Isolated	High	High	Limited	LowRisk
North Fork Trinchera Creek	RG Headwaters	13010002cp014	YES	83	2006	Unaltered (< 1%)	NO	None	YES	NO	Complete	11.5	Isolated	High	Moderate	Limited	LowRisk
South Fork West Indian Creek, West Indian	RG Headwaters	13010002cp015	YES	716	2008	Unaltered (< 1%)	NO	None	YES	YES	Partial	17.1	Isolated	High	Low	Limited	LowRisk
Lower Placer, Sangre De Cristo, Wagon	RG Headwaters	13010002cp016	YES	6,719	2011	Unaltered (< 1%)	NO	None	YES	NO	Partial	63	Weakly	Moderate	Moderate	Moderate	LowRisk
Upper Placer, Grayback	RG Headwaters	13010002cp021	YES	4,491	2013	>1% and <=10%	NO	None	NO	NO	Complete	45.7	Weakly	Moderate	Moderate	Moderate	LowRisk
Little Ute Creek	RG Headwaters	13010002cp017	YES	143	2004	Unaltered (< 1%)	NO	None	NO	NO	Complete	2.7	Isolated	Moderate	Moderate	Limited	LowRisk
Cuates Creek	RG Headwaters	13010002cp018	YES	274	calc	NT-Sus_Un	NO	<10km	Unknown	NO	Complete	5.5	Isolated	High	Very Low	Limited	LowRisk
Torcido Creek	RG Headwaters	13010002cp019	YES	660	2005	Unaltered (< 1%)	NO	None	NO	NO	Complete	3.3	Isolated	Moderate	Low	Limited	LowRisk
Alamosito Creek	RG Headwaters	13010002cp020	YES	15	2012	Unaltered (< 1%)	NO	None	YES	NO	None	0.8	Isolated	High	Low	Limited	LowRisk
Medano Creek	RG Headwaters	13010003cp001	YES	2,354	2011	Unaltered (< 1%)	NO	None	NO	NO	Complete	28.8	Weakly	High	Low	Limited	LowRisk
East Pass Creek	RG Headwaters	13010004cp002	YES	138	2005	Unaltered (< 1%)	NO	None	NO	NO	Complete	11.2	Isolated	Moderate	Very Low	Limited	LowRisk
Whale Creek	RG Headwaters	13010004cp001	YES	138	2003	Unaltered (< 1%)	NO	None	NO	NO	Complete	4.2	Isolated	Moderate	Low	Limited	LowRisk
Cross Creek	RG Headwaters	13010004cp003	YES	1,382	2005	Unaltered (< 1%)	NO	None	NO	NO	Complete	12.9	Isolated	Moderate	Low	Moderate	LowRisk
Jacks Creek	RG Headwaters	13010004cp003L	YES	1,818	2005	Unaltered (< 1%)	NO	None	YES	NO	Complete	18.5	Isolated	Moderate	Low	Moderate	LowRisk
East Middle Creek	RG Headwaters	13010004cp004	YES	193	2011	>1% and <=10%	NO	None	NO	NO	Complete	4.9	Isolated	Moderate	Low	Minimal	LowRisk
Big Springs Creek	RG Headwaters	13010004cp006	YES	240	2007	Unaltered (< 1%)	NO	None	NO	NO	Complete	4.1	Isolated	Moderate	Low	Limited	LowRisk
Middle Fork Carnero Creek	RG Headwaters	13010004cp007	YES	129	2005	Unaltered (< 1%)	NO	None	NO	NO	Complete	11.3	Isolated	Moderate	Low	Limited	LowRisk
North Fork Carnero Creek	RG Headwaters	13010004cp008	**NO**	-	2005	Unaltered (< 1%)	NO	None	NO	NO	Complete	13	Isolated	Moderate	Very Low	Limited	LowRisk
South Carnero Creek	RG Headwaters	13010004cp010	YES	1,406	2006	Unaltered (< 1%)	NO	<10km	YES	NO	None	22.7	Isolated	Moderate	Moderate	Limited	LowRisk
Miners Creek, Prong Creek	RG Headwaters	13010004cp011	YES	678	2006	>1% and <=10%	NO	None	YES	NO	None	13	Isolated	Moderate	Low	Limited	LowRisk
Cave Creek	RG Headwaters	13010004cp012	YES	154	2001	Unaltered (< 1%)	NO	None	YES	NO	None	10.2	Isolated	High	Low	Limited	LowRisk
Tio Grande	RG Headwaters	13010005cp001	YES	392	2004	Unaltered (< 1%)	NO	None	YES	NO	Complete	7.6	Isolated	High	Very Low	Limited	LowRisk
Tio Grande	RG Headwaters	13010005cp002	YES	436	2004	NT-Sus_Un	NO	None	YES	NO	Complete	4.5	Isolated	High	Low	Limited	Acute
Tanques Creek	RG Headwaters	13010005cp003	YES	188	2010	Unaltered (< 1%)	NO	None	YES	NO	Complete	2.9	Isolated	High	Low	Limited	LowRisk
Rio Nutritas	RG Headwaters	13010005cp004	YES	86	2001	Unaltered (< 1%)	NO	None	YES	NO	None	5.1	Isolated	High	Low	Limited	LowRisk

Table C14. Summary data used in the Rio Grande cutthroat trout status assessment model.

Conservation_Population	GMU	CP_Pop_ID	EXTANT	Ne_Est	Ne_Yr	Genetic status	RBT_Pres	Hyb_Risk	Com_Nnat	Supp	Barrier	Str_Lth	Networked	Fire_Risk	Flow_Cat	Disease_Risk	Temp_Risk
Osier Creek	RG Headwaters	13010005cp006	YES	361	2010	Unaltered (< 1%)	NO	None	NO	NO	Complete	5.9	Isolated	High	Low	Limited	LowRisk
Lake Fork Conejos River	RG Headwaters	13010005cp007	YES	71	2004	Unaltered (< 1%)	NO	None	NO	NO	Complete	1	Isolated	High	Low	Minimal	LowRisk
Lake Fork Conejos River	RG Headwaters	13010005cp008	YES	673	2012	Unaltered (< 1%)	NO	None	NO	NO	Complete	4	Isolated	High	Moderate	Moderate	LowRisk
Rio de los Pinos	RG Headwaters	13010005cp009	YES	42	2005	Unaltered (< 1%)	NO	None	NO	NO	Complete	0.9	Isolated	High	High	Limited	LowRisk
Cascade Creek	RG Headwaters	13010005cp010	YES	892	2000	Unaltered (< 1%)	NO	None	NO	NO	Complete	4.7	Isolated	High	Low	Limited	LowRisk
Costilla Creek, State Line Creek	Lower RG	13020101cp001	YES	1,122	2008	>1% and <=10%	NO	None	NO	NO	Complete	14.6	Weakly	High	Low	Limited	LowRisk
Costilla, Frey, Glacier, Patten Creeks	Lower RG	13020101cp002	YES	2,488	2010	Unaltered (< 1%)	NO	None	NO	NO	Complete	15.2	Moderately	High	Low	Limited	LowRisk
E. Unnamed Trib. #2 to Costilla Creek (Powderhouse)	Lower RG	13020101cp003	YES	378	2009	Unaltered (< 1%)	NO	None	NO	NO	Complete	6.2	Isolated	High	Low	Limited	LowRisk
E. Unnamed Trib. #2 to Costilla Creek (Powderhouse)	Lower RG	13020101cp004	YES	28	2004	NT-Sus_Hyb	NO	>10km	YES	NO	Complete	2.1	Isolated	High	Very Low	Limited	LowRisk
NW Unnamed Trib. to Costilla Creek (La Cueva)	Lower RG	13020101cp005	YES	109	2010	>1% and <=10%	NO	<10km	NO	NO	None	5.1	Isolated	High	Very Low	Limited	LowRisk
Comanche, Gold, Grassy, Holman, LaBelle Creeks	Lower RG	13020101cp006	YES	2,863	2012	Unaltered (< 1%)	NO	None	NO	NO	Complete	44.7	Moderately	High	Low	Limited	LowRisk
Chuck Wagon, Comanche, Fernandez Creeks	Lower RG	13020101cp007	YES	148	2010	>1% and <=10%	NO	None	NO	NO	Complete	8.6	Weakly	High	Low	Limited	LowRisk
Lower (Chuck Wagon, Comanche, Fernandez)	Lower RG	13020101cp007L	YES	237	2012	NT-Sus_Hyb	YES	Symp	NO	NO	None	5.5	Weakly	High	Low	Limited	Acute
Unnamed Trib. to Ute Creek	Lower RG	13020101cp008	YES	471	2005	Unaltered (< 1%)	NO	<10km	NO	NO	None	13.8	Isolated	High	Low	Limited	Chronic
Cabresto Creek	Lower RG	13020101cp009	YES	373	2013	Unaltered (< 1%)	NO	>10km	YES	NO	Partial	13.7	Isolated	High	Low	Minimal	LowRisk
Bitter Creek	Lower RG	13020101cp010	YES	204	2006	Unaltered (< 1%)	NO	>10km	NO	NO	Partial	2.9	Isolated	High	Very Low	Minimal	LowRisk
Columbine, Deer, PlacerFk, Willow Creeks	Lower RG	13020101cp011	YES	660	2010	Unaltered (< 1%)	NO	None	NO	NO	Complete	10.7	Moderately	High	Moderate	Limited	LowRisk
Lower (Columbine, Deer, Placer Fork, Willow)	Lower RG	13020101cp011L	YES	438	2010	Unaltered (< 1%)	NO	None	YES	NO	None	7.1	Moderately	High	Moderate	Limited	LowRisk
San Cristobal Creek	Lower RG	13020101cp012	YES	268	2006	Unaltered (< 1%)	NO	None	NO	NO	None	6.5	Isolated	High	Low	Limited	LowRisk
Yerba Creek	Lower RG	13020101cp013	YES	115	2005	Unaltered (< 1%)	NO	>10km	YES	YES	Partial	4.7	Isolated	High	Low	Limited	LowRisk
Italianos Creek	Lower RG	13020101cp015	YES	114	2005	NT-Sus_Un	NO	>10km	NO	NO	Complete	3.8	Isolated	High	Low	Limited	LowRisk
Gavilan Creek	Lower RG	13020101cp016	YES	133	2005	Unaltered (< 1%)	NO	>10km	YES	NO	None	3.4	Isolated	High	Low	Limited	LowRisk
South Fork Rio Hondo	Lower RG	13020101cp017	YES	142	2005	Unaltered (< 1%)	NO	>10km	YES	NO	None	6.3	Isolated	High	Moderate	Limited	LowRisk
Tienditas Creek	Lower RG	13020101cp018	YES	19	est	Unaltered (< 1%)	NO	>10km	YES	NO	None	3.2	Isolated	High	Low	Limited	LowRisk
Frijoles Creek	Lower RG	13020101cp019	YES	169	2008	Unaltered (< 1%)	NO	None	YES	NO	Partial	5	Isolated	High	Low	Limited	LowRisk
Palociento Creek	Lower RG	13020101cp020	YES	91	est	Unaltered (< 1%)	NO	None	YES	YES	Complete	3.9	Isolated	High	Low	Limited	LowRisk
Rio Grande del Rancho	Lower RG	13020101cp021	YES	182	calc	>1% and <=10%	NO	>10km	YES	NO	None	4.3	Isolated	High	Low	Limited	LowRisk
Rito la Presa	Lower RG	13020101cp022	YES	648	2008	Unaltered (< 1%)	NO	>10km	NO	NO	None	9.1	Isolated	High	Moderate	Minimal	LowRisk
Lower (Rito La Presa)	Lower RG	13020101cp022L	YES	135	est	Unaltered (< 1%)	NO	>10km	YES	NO	None	5.8	Isolated	High	Moderate	Minimal	LowRisk
Policarpio Creek	Lower RG	13020101cp023	YES	261	2005	Unaltered (< 1%)	NO	None	NO	NO	Complete	4.8	Isolated	High	Low	Limited	LowRisk
Unnamed Trib. to Rio Pueblo (Osha)	Lower RG	13020101cp024	YES	33	2005	>1% and <=10%	NO	None	NO	NO	Complete	8.8	Isolated	High	Low	Limited	LowRisk
Rito Angostura	Lower RG	13020101cp025	YES	573	2003	>1% and <=10%	NO	None	NO	NO	Complete	6.4	Isolated	High	Low	Limited	LowRisk
Alamitos Creek	Lower RG	13020101cp026	YES	438	2010	Unaltered (< 1%)	NO	>10km	NO	NO	Complete	4.1	Isolated	High	Low	Minimal	LowRisk
Lower (Alamitos)	Lower RG	13020101cp026L	**NO**	-			NO				None	7.3	Isolated	High	Moderate		LowRisk
Middle Fork Rio Santa Barbara	Lower RG	13020101cp027	YES	357	2003	Unaltered (< 1%)	NO	None	YES	NO	Complete	7	Isolated	High	High	Limited	LowRisk
East Fork Rio Santa Barbara	Lower RG	13020101cp028	YES	169	2009	Unaltered (< 1%)	NO	None	YES	NO	Partial	4.1	Isolated	High	Moderate	Limited	LowRisk
Rio Santa Barbara	Lower RG	13020101cp029	YES	463	2009	NT-Sus_Hyb	NO	<10km	YES	NO	None	14.5	Isolated	High	Moderate	Limited	LowRisk
Rio de las Trampas	Lower RG	13020101cp030	YES	548	calc	NT-Sus_Hyb	NO	<10km	NO	NO	None	8.2	Isolated	High	Moderate	Limited	LowRisk
Rio San Leonardo	Lower RG	13020101cp031	YES	299	calc	NT-Sus_Hyb	NO	<10km	NO	NO	Partial	5.8	Isolated	High	Low	Limited	LowRisk
Rio de la Cebolla, Truchas	Lower RG	13020101cp032	YES	545	2007	Unaltered (< 1%)	NO	<10km	NO	NO	Partial	17.2	Isolated	High	Moderate	Limited	LowRisk
Rio Quemado	Lower RG	13020101cp034	YES	1,223	2007	NT-Sus_Un	NO	None	NO	NO	None	16.8	Isolated	High	Moderate	Limited	LowRisk
Jicarita Creek	Lower RG	13020101cp035	YES	169	calc	Unaltered (< 1%)	NO	None	NO	NO	Partial	4.1	Isolated	High	Moderate	Limited	LowRisk
Unnamed Trib. to Rio Santa Barbara (Indian)	Lower RG	13020101cp036	YES	94	calc	NT-Sus_Hyb	NO	None	Unknown	NO	Complete	2.8	Isolated	High	Low	Limited	LowRisk
Rio Medio	Lower RG	13020101cp037	YES	1,285	calc	NT-Sus_Hyb	YES	Symp	YES	NO	None	13.1	Isolated	High	Low	Limited	LowRisk

Table C14. Summary data used in the Rio Grande cutthroat trout status assessment model.

Conservation_Population	GMU	CP_Pop_ID	EXTANT	Ne_Est	Ne_Yr	Genetic status	RBT_Pres	Hyb_Risk	Com_Nnat	Supp	Barrier	Str_Lth	Networked	Fire_Risk	Flow_Cat	Disease_Risk	Temp_Risk
Rio Frijoles, Rio Jaroso	Lower RG	13020101cp038	YES	1,109	1992	NT-Sus_Hyb	YES	Symp	YES	NO	None	12.5	Isolated	High	Low	Limited	LowRisk
Rio Molino	Lower RG	13020101cp040	YES	273	2012	Unaltered (< 1%)	NO	None	NO	NO	Complete	5.6	Isolated	High	Low	Limited	LowRisk
Casias Creek	Lower RG	13020101cp041	YES	818	2013	Unaltered (< 1%)	NO	None	NO	NO	Complete	7.1	Moderately	High	Moderate	Limited	LowRisk
Nabor Creek	Lower RG	13020102cp001	YES	447	2006	Unaltered (< 1%)	NO	None	NO	NO	Complete	5.9	Isolated	High	Very Low	Limited	LowRisk
Little Willow Creek	Lower RG	13020102cp002	YES	279	2002	NT-Sus_Hyb	YES	Symp	NO	NO	Complete	3.7	Isolated	High	Low	Limited	LowRisk
Poso Creek	Lower RG	13020102cp003	YES	281	2005	NT-Sus_Hyb	NO	None	YES	YES	Complete	3.9	Isolated	High	Very Low	Limited	LowRisk
Jaroso Creek	Lower RG	13020102cp004	YES	240	2003	NT-Sus_Hyb	NO	None	NO	NO	None	8	Isolated	High	Very Low	Limited	LowRisk
Canjilon Creek	Lower RG	13020102cp005	YES	642	2004	>1% and <=10%	NO	<10km	NO	NO	None	8.1	Isolated	High	Low	Limited	LowRisk
El Rito	Lower RG	13020102cp006	YES	1,786	2008	Unaltered (< 1%)	NO	None	NO	NO	Complete	12.7	Isolated	High	Moderate	Limited	LowRisk
El Rito	Lower RG	13020102cp007	YES	1,450	2008	NT-Sus_Hyb	YES	Symp	YES	NO	Complete	5.3	Isolated	High	Moderate	Limited	Acute
Canones Creek	Lower RG	13020102cp008	YES	1,849	2010	Unaltered (< 1%)	NO	None	NO	NO	Complete	10.7	Isolated	High	Low	Limited	LowRisk
Polvadera Creek	Lower RG	13020102cp009	YES	0	2010	Unaltered (< 1%)	NO	None	NO	NO	Complete	13.1	Isolated	High	Very Low	Limited	LowRisk
Rio Del Oso, Rito De Abiquiu, Rito Del Oso	Lower RG	13020102cp010	**NO**	-	2012	NT-Sus_Un	NO	None	NO	NO	None	12.5	Isolated	High	Very Low	Limited	LowRisk
Wolf Creek	Lower RG	13020102cp011	YES	20	2010	>10% and <=20%	NO	None	YES	NO	Complete	0.6	Isolated	High	Low	Limited	LowRisk
East Fork Wolf Creek	Lower RG	13020102cp012	YES	513	2009	Unaltered (< 1%)	NO	None	NO	NO	Complete	3.7	Isolated	High	Very Low	Limited	LowRisk
Capulin Creek	Lower RG	13020201cp001	**NO**	-	2012	Unaltered (< 1%)	NO	None	NO	NO	None	12	Isolated	High	Low	Limited	LowRisk
Medio Dia Creek	Lower RG	13020201cp002	**NO**	-	2012	NT-Sus_Un	NO	None	NO	NO	None	0.7	Isolated	High	Very Low	Limited	LowRisk
Rio Cebolla	Lower RG	13020202cp001	YES	539	2012	NT-Sus_Un	NO	None	YES	YES	Complete	7.3	Isolated	High	Low	Moderate	LowRisk
Rito de las Palomas	Lower RG	13020202cp002	YES	404	calc	Unaltered (< 1%)	NO	None	YES	NO	None	6.9	Isolated	High	Very Low	Limited	LowRisk
Rio de Las Vacas, Anastacio, de las Perchas	Lower RG	13020202cp003	YES	662	na	>1% and <=10%	NO	None	NO	NO	Complete	4.5	Weakly	High	Low	Limited	LowRisk
Lower (Las Vacas, Anastacio, de las Perchas)	Lower RG	13020202cp003L	YES	2,266	na	>1% and <=10%	NO	None	YES	YES	None	15.4	Weakly	High	Low	Limited	LowRisk
La Jara Creek	Lower RG	13020204cp001	YES	26	est	>1% and <=10%	NO	None	NO	NO	None	4.4	Isolated	High	Low	Limited	LowRisk
Rito de los Pinos	Lower RG	13020204cp002	YES	54	est	NT-Sus_Un	NO	None	YES	NO	Complete	2.3	Isolated	High	Very Low	Limited	LowRisk
Rio Puerco	Lower RG	13020204cp003	YES	1,418	2009	>1% and <=10%	NO	None	NO	NO	None	14.4	Isolated	High	Low	Limited	LowRisk
Rio Mora	Pecos	13060001cp001	YES	75	calc	Unaltered (< 1%)	NO	None	Unknown	NO	None	2.4	Isolated	High	Low	Limited	LowRisk
Unnamed Trib. to Rio Mora	Pecos	13060001cp002	YES	115	calc	>1% and <=10%	NO	None	Unknown	NO	Partial	3.2	Isolated	High	Low	Limited	LowRisk
Rio Valdez	Pecos	13060001cp003	YES	135	2004	Unaltered (< 1%)	NO	None	NO	NO	Complete	3.7	Isolated	High	Moderate	Limited	LowRisk
Pecos River	Pecos	13060001cp004	YES	425	2003	>1% and <=10%	NO	None	NO	NO	Complete	6.3	Isolated	High	Low	Limited	LowRisk
Rito Del Padre, Rito Maestas	Pecos	13060001cp005	YES	668	1990	>1% and <=10%	NO	<10km	YES	NO	Complete	9.9	Isolated	High	Low	Limited	LowRisk
Rito los Esteros	Pecos	13060001cp006	YES	80	calc	Unaltered (< 1%)	NO	<10km	YES	NO	None	2.5	Isolated	High	Low	Limited	LowRisk
Jacks Creek	Pecos	13060001cp007	YES	561	2003	Unaltered (< 1%)	NO	<10km	NO	NO	Complete	11.3	Isolated	High	Low	Moderate	LowRisk
Cave Creek	Pecos	13060001cp008	YES	89	calc	>1% and <=10%	NO	None	Unknown	NO	Partial	2.7	Isolated	High	Low	Limited	LowRisk
Macho Creek	Pecos	13060001cp009	YES	153	2002	Unaltered (< 1%)	NO	<10km	NO	NO	Complete	3.4	Isolated	High	Very Low	Limited	LowRisk
Dalton Creek	Pecos	13060001cp010	YES	69	2006	Unaltered (< 1%)	NO	<10km	NO	NO	Complete	6.7	Isolated	High	Low	Moderate	LowRisk
Bear Creek	Pecos	13060001cp011	YES	282	calc	NT-Sus_Un	NO	None	NO	NO	Complete	5.6	Isolated	High	Low	Limited	LowRisk
Pinelodge Creek	Pecos	13060005cp001	YES	29	2010	Unaltered (< 1%)	NO	None	NO	NO	Complete	3.9	Isolated	High	Very Low	Limited	Acute

APPENDIX D

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