# STATUS REVIEW

## Lahontan cutthroat trout (*Oncorhynchus clarkii henshawi*)

## I. GENERAL INFORMATION

**Species:** Lahontan cutthroat trout

**Date listed:** Endangered October 13, 1970; reclassified as threatened July 16, 1975

**FR citations:** 35 FR 16057–16048; 40 FR 29863–29864

**Classification:** Threatened species

**Rulemakings:** A special rule under Endangered Species Act (Act) section 4(d) was published in conjunction with the reclassification in 1975 to facilitate management by the States and allow State-permitted sport harvest (Service 1975).

### Species Overview

Lahontan cutthroat trout (LCT) is a subspecies of inland trout native to the hydrographic Lahontan Basin, which contains a large portion of northern Nevada, the northern portion of the eastern Sierra Nevada mountains of California, and a small portion in southeastern Oregon (Figure 1). On October 13, 1970, LCT was federally listed as endangered under the Endangered Species Conservation Act of 1969 but was reclassified to threatened with a 4(d) rule on July 16, 1975, to allow for state management and regulated angling (Service 1975). Critical habitat is not designated for LCT. Several documents have been written by the U.S. Fish and Wildlife Service (Service) and recovery partners over the last 25 years that synthesize much of what we know about LCT today; this document builds upon that information and formally reviews the status of LCT. The documents that are referenced most by this review include the 1995 Recovery Plan for LCT (Service 1995), the 2009 5-Year Review (Service 2009), and the Updated Goals and Objectives for the Conservation of LCT (2019 UGOs; LCT Coordinating Committee 2019). To improve flow and readability of this document, references to these existing resources were kept to a minimum. In addition, much of the technical information used to develop and complete the analysis used in this review is included as appendices.

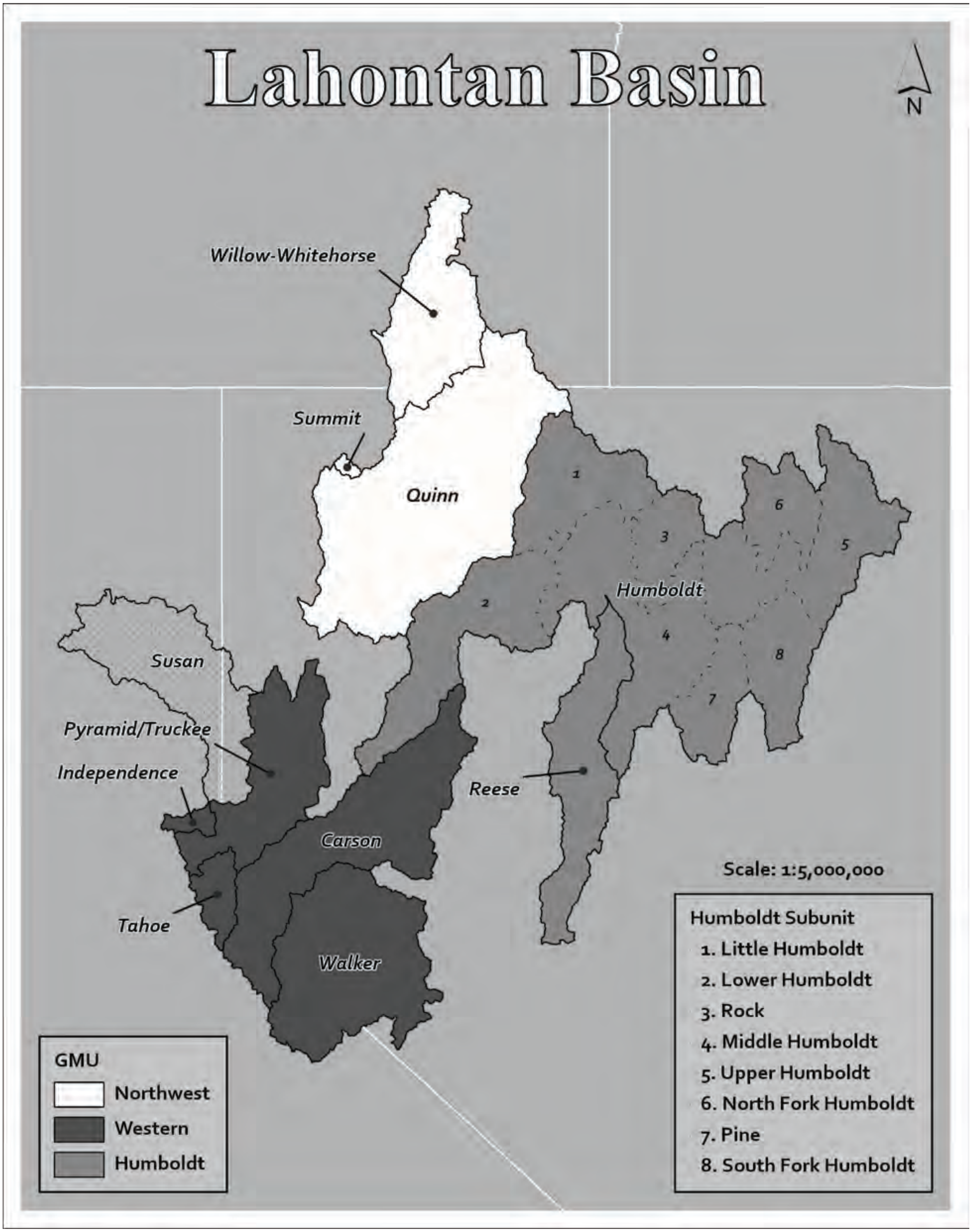


**Figure 1.** Map depicting the different Geographic Management Units (GMUs) from the 1995 Recovery Plan and the current LCT Management Units (2019 UGOs) within the Lahontan Basin.

LCT evolved within the large Pleistocene-era Lake Lahontan, which has since fragmented into a network of smaller lakes, rivers, and streams due to ongoing climate warming that is now exacerbated by climate-change and other anthropogenic factors. Nonetheless, due to the lake's natural, gradual desiccation, LCT developed life-history strategies and characteristics to adapt to the new and different types of habitats available to it within the different river basins. This resulted in both fluvial and adfluvial life-histories, with residential and migratory individuals being present in healthy, interconnected meta-populations. Prior to Western settlement, LCT occupied the majority of large freshwater and alkaline lakes, small mountain and tributary streams, and all the major rivers within its historical range; connected systems would have likely functioned as large, interconnected meta-populations. However, anthropogenic impacts including over-harvest, mining, logging, grazing, pollution, water diversions, dams and reservoirs, and non-native trout introductions significantly reduced LCT's viability due to declining habitat quality, quantity, and connectedness. By the 1950s, LCT had been extirpated from most of its historical habitat and was constricted to isolated fragments.

Recovery of LCT was originally divided into the Humboldt, Western, and Northwest distinct vertebrate population segments (DPSs), later termed Geographic Management Units (GMUs), in 1995. This occurred because DPSs, as described under the Service's 1996 DPS policy, were never formally established. To simplify implementation planning for this wide-ranging species, the GMUs were dissolved and 10 LCT Management Units (LMUs) were created in 2019, defined by river basins and/or differences in management needs. Each LMU contains its own spatially explicit conservation objectives. The Humboldt Management Unit was further sub-divided into hydrologic units because it is large in area and was already managed this way (see Figure 1 and the 2019 UGOs for more information). Lastly, the historically occupied Susan River watershed was originally included in the Western GMU, but because LCT were not known to exist there in 2019 it was assumed that LCT could be recovered without it; thus, it has not been assigned its own LMU. This does not preclude including the Susan River in recovery planning updates or LCT reintroductions in the future though.

The LMUs contain locally derived Recovery Implementation Teams (RITs) of relevant interagency and non-governmental managers, biologists, researchers, and technicians that develop and implement LCT recovery projects within their respective LMU. These RITs are guided by a governance structure that includes the Coordinating Committee (CC) and Management Oversight Group (MOG) (Figure 2). The CC includes management representatives from the interagency partners and is responsible for acting as the liaison between the MOG and RITs to ensure efficient prioritization and coordination of LCT projects range wide. The MOG is comprised of senior-level leadership from the various Federal, State, and local agencies and Tribes responsible for the management of LCT with the goal of improving coordination at the executive level to better allocate resources for LCT recovery and remediate long-standing challenges (Appendix A: List of Recovery Partners).

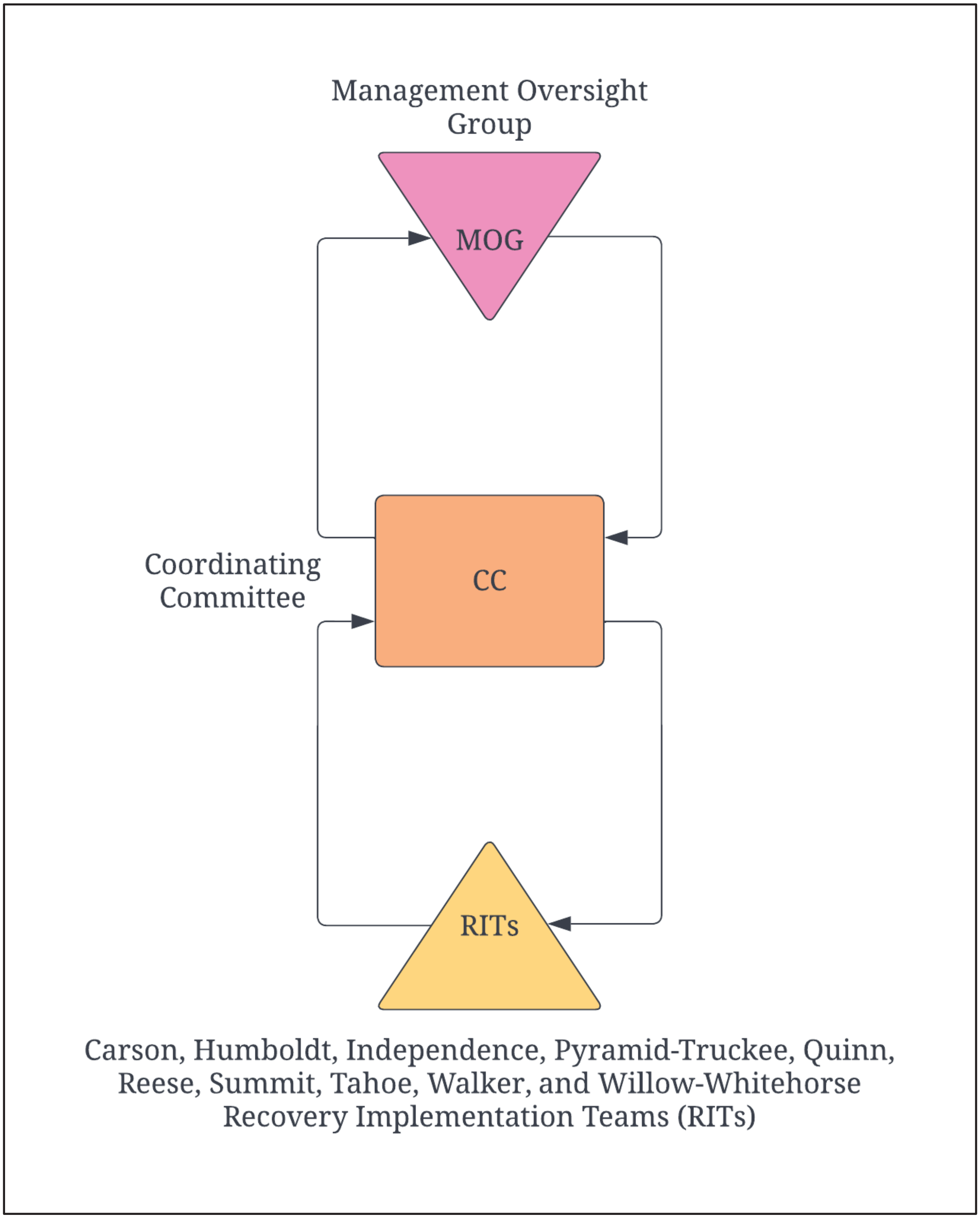


**Figure 2.** LCT Interagency governance structure.

## Methodology Used to Complete This Review

In accordance with section 4(c)(2) of the Endangered Species Act of 1973 (ESA), as amended, the purpose of a Status Review is to assess each threatened species and endangered species to determine whether its status has changed, and if it should be reclassified or removed from the Lists of Threatened and Endangered Wildlife and Plants as defined by the ESA. It was essential to first develop a baseline status of LCT, which has newly recognized evolutionary depth and diversity (Peacock *et al.* 2018, Trotter *et al.* 2018), by fully synthesizing, cross-walking, and building upon past information and current data. The Service used its 1995 Recovery Plan, the 2019 UGOs, the 2009 5-Year Review, State Management Plans (Sevon *et al.* 1999, Elliott 2004, Gerstung 1986), other agency records, scientific literature, a database and associated population viability assessment (PVA) application (Leasure *et al.* 2019, Neville *et al*. 2019), and information from experts who monitor or research this species in various localities to do so. All this information is now collated and will be placed in the pending Conservation Efforts Database for LCT to allow for more efficient future analyses and further scientific inquiry.

This review analyzed the status of LCT under the 3-R's Framework of Representation, Redundancy, and Resiliency, which is the current standard for Service Species Status Assessments (SSAs) and Status Review documents (Shaffer and Stein 2000, Haak and Williams 2012, Wolf *et al.* 2015, Service 2016, Smith *et al.* 2018). Representation describes the ability of a species to adapt to a changing environment over time (*i.e.*, retain its adaptive capacity). Redundancy is defined as the capability of a species to withstand catastrophic events. Resiliency is the ability of a species to withstand normal, stochastic disturbances. A more detailed description of the framework and the specific analyses that were performed in this review can be found in Appendix B: Technical Methods. In short, the 3-R's Framework for LCT was designed to best conserve the adaptive capacity of LCT by ensuring that each of the 10 LMU's contain redundant and resilient populations. This should preserve the genetic and behavioral diversity of the species in ecologically and geographically representative habitat throughout its historical range. To assess progress towards the 2019 UGOs and its 3-R's goals, spatially explicit objectives were established for each LMU. By tracking those objectives and rolling that information up to assess progress related to the 3-R's, a baseline of the status of LCT was developed here, which can then be tracked through time in subsequent Status Reviews to assess progress.

Achieving resiliency is a population-level goal. A population here is defined as a group (or groups, *i.e.*, a meta-population) of individuals that can interbreed within a stream, river, and/or lake system. Resiliency was assessed at the population level through the measurement, estimation, and synthesis of recent and available data related to five demographic and genetic health metrics, including: (1) population abundance, (2) number of age-classes, (3) effective population size, (4) genetic diversity, and (5) hybridization status. These metrics were chosen because they represent a balanced yet diverse suite of resiliency-oriented categories that are well-accepted within the scientific community; in addition, data for these metrics were generally available and comparable for many of the populations analyzed. A scoring matrix was then developed specifically for this application and was used to categorically rank each of these metrics (Table 1). Bins for ranking each metric were developed based on generally accepted scientific literature and supported by most experts in these fields.

**Table 1.** LCT population resiliency metrics and scoring matrix used to assess the resiliency of each LCT population in this review; see details by population in Table 2/Appendix C. Rankings for each metric were totaled and divided by five to derive a resiliency score for each population.

| Rank | Abundance (N) | Number of Age Classes | Effective Population Size ($N_e$) | Genetic Diversity* ($H_e/H_o$) | Hybridization Status (% LCT) |
|---|---|---|---|---|---|
| 4 | 2,501+ | 5+ | 501+ | 0.8+ | 99%+ |
| 3 | 1,001 – 2,500 | 4 | 251 – 500 | 0.65 – 0.79 | 97 – 98.9% |
| 2 | 501 – 1,000 | 3 | 101 – 250 | 0.4 – 0.64 | 90 – 96.9% |
| 1 | 100 – 500 | 2 | 50 – 100 | < 0.4 | 75 – 89.9% |
| 0 | < 100 | 1 | 0 – 49 | N/A | < 75% |

**See Appendix B: Technical Methods for more information about these rankings, as several types of data were averaged together to generally describe genetic diversity for a population.*

The scores for each metric were then averaged to assign each LCT population managed for recovery purposes a resiliency score:

- A score above 3.0 indicated a population that is likely *resilient*;
- A score between 2.0 and 2.9 indicated a population that is *potentially resilient*;
- A score between 1.0 and 1.9 indicated a population that is *unlikely to be resilient*; and
- A score below 0.9 indicated a population that is *at risk of extirpation*.

The data-driven scores were then cross-checked through an expert opinion exercise to ensure the best available information was included and the scores reflected actual, on-the-ground conditions. This process resulted in the reassignment of several populations as the categories were relatively crude and the interpretation of this specific application required some level of review and adaptation. This occurred mostly when a population ranked on the very high or low end of a category. In addition, information from the expert opinion exercise also helped to rank a population where no or limited data existed, providing a more accurate and complete picture of the status of LCT rangewide. The resiliency categories were not designed to be binary (resilient or not resilient) but instead to reflect a continuum of likelihood that the population is to persist through time. For example, a population scoring in the *potentially resilient* category contains some lower level of resiliency, which in many cases could be increased through time (and *visa versa* for populations currently in the *resilient* category).

With population resiliency assessed, that information could then be rolled up to evaluate progress related to the goals of redundancy and representation. In short, redundancy was assessed by determining how many resilient populations were present within each of the LMUs and representation by how many of the LMUs had a completed set of objectives (based on the 2019 UGOs). Please see Appendix B: Technical Methods for a full description of the methods used to complete this status review.

FR Notice Citation Announcing the Species is Under Active Review

A notice announcing initiation of the Status Review of this taxon and the opening of a 60-day public comment period was published in the Federal Register on February 2, 2022 (Service 2022). The Service followed that announcement up by sending hard and email copies of it to interested parties. To prepare and complete this Status Review, the Service initiated communication *via* email and phone to all interagency and non-governmental technical staff known to collect/compile/house LCT-related data starting in October of 2021 and continued following up on those requests through August of 2022.

## II. REVIEW ANALYSIS

### Application of the 1996 Distinct Population Segment (DPS) Policy

Although the 1995 Recovery Plan defines three DPSs for LCT, these delineations were prior to the issuance of the 1996 DPS policy and were not defined as DPSs in a formal rulemaking process. The 2019 UGOs uses the term LCT Management Units (LMUs) to delineate alike LCT populations, but the LMUs were not formally submitted to the Federal Register. Thus, the DPS policy was not applied to this review for LCT and will not be further addressed. LCT is listed as a single entity, wherever found.

### Updated Information and Current Species Status

Spatial Distribution

It is not known with certainty every system that LCT occupied before Western settlement; historical fisheries data and reports, published historical accounts, locations of known barriers and professional knowledge were used to create a Geographic Information System (GIS) layer depicting what is believed to be historically occupied habitat. Due to anthropogenic influences including barrier installation, climate change, and habitat loss, fragmentation, and degradation, not all historically occupied habitat is currently suitable for LCT; to address these changes, an additional GIS layer was created to depict what is potentially suitable habitat today using data derived from professional reports and knowledge of the modern landscape. This spatial distribution information, in combination with the currently occupied habitat layer for LCT, was used in developing the 2019 UGOs.

The historically occupied, potentially suitable, and currently occupied habitat layers were then updated for this review (Figure 3). The occupied habitat layer update included general distribution updates and the addition of creeks from reintroductions or those that were previously believed to be extirpated prior to environmental DNA (eDNA) results indicating otherwise (*e.g.*, lower Marys River mainstem, Brown Creek, Tierney Creek). The upper distribution of some streams in the different layers were adjusted to reflect additional knowledge of upstream natural barriers and steep gradients; these changes are reflected in all relevant layers.

Currently, LCT occupy approximately 12.0 percent of its historical habitat, and 17.5 percent of potentially suitable habitat (Figure 3). However, LCT's spatial distribution is overestimated because several systems (*e.g.*, Carson River) withing the Lahontan Basin are occupied solely because they are stocked, along with other sportfish, to meet recreational angling demand. Many sportfish species, including LCT and other non-native trout, are stocked in these systems each year to provide the angling public fish to catch and keep; most of these stocked fish do not survive through the winter and reproduction and recruitment are not usually tracked in a meaningful way. Because these systems are not managed to conserve LCT, but instead to provide recreational opportunities, they were not analyzed in this review. Several out-of-historical-range populations of LCT also exist (see Table A-4 in the 2019 UGOs) but they were not specifically analyzed in this review. This is because of an overall lack of data/information and because they were not generally included in the 2019 UGOs. However, some of these populations may be part of the recovery equation in the future; they are being sampled now as part of a larger project to inform the development of an LCT Genetics Management Plan (GMP) as mentioned in the 2019 UGOs. The remainder of these populations are not managed for recovery purposes currently and largely exist to fulfill recreational angling demand and to provide increased awareness of LCT.

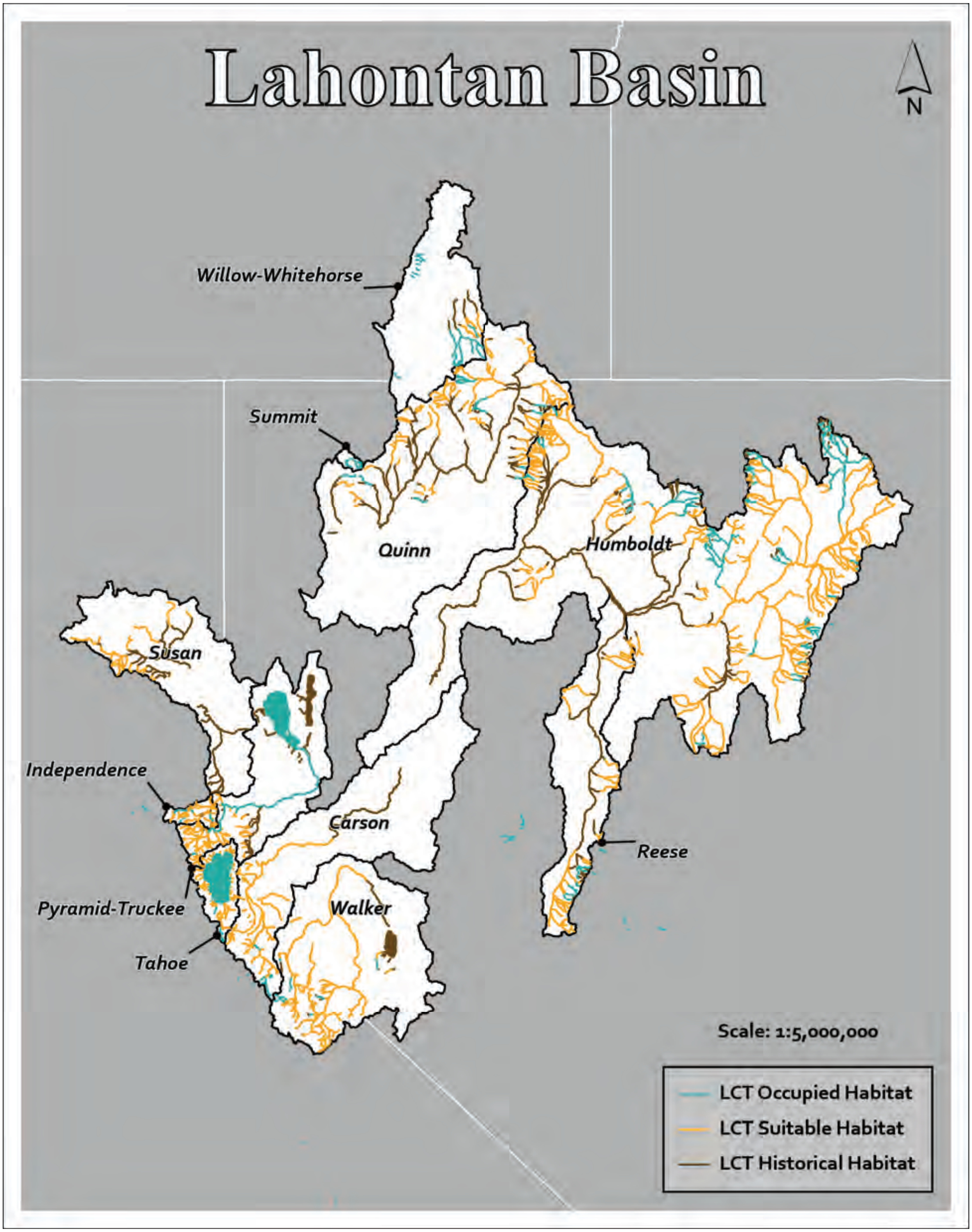


**Figure 3.** Rangewide occupied habitat map for LCT (blue), with currently suitable (yellow) and historical habitat (brown) also displayed in each of the 10 LCT Management Units.

Threats Analysis

The 2009 LCT 5-Year Review presented a robust synthesis of the threats to LCT, and those threats have not changed significantly since then (Service 2009). Non-native trout, habitat loss and fragmentation, and habitat degradation remain the greatest threats to this species. In general, the threat of hybridization with non-native rainbow trout seems greater now than it was in the past; there are likely several reasons for this. More advanced tools, such as improved genetic analyses and eDNA, allow for more efficient and effective genomic and population-level coverage resulting in more detailed information. In addition, recovery partners are more regularly checking for hybridization since 2019 samples from a pending publication (Hemstrom *et al.* 2022) determined hybrid individuals were present in populations where recovery partners did not think hybridization could occur or was occurring. The repeated presence of recent LCT-rainbow trout hybrids in a variety of locations indicates that this is as much a contemporary (and potentially increasing) threat as a past one. It is also clear now that past hybridization events, in some cases, resulted in population-level introgression that may be challenging to manage in the future. Moreover, poor to moderate habitat conditions throughout much of northern Nevada, especially at lower elevations, continue to threaten potential LCT recovery populations by reducing available habitat and connectivity (see more detailed descriptions within Appendix C: Technical Results). Lastly, climatic changes are likely affecting, and likely will continue to threaten, potential LCT recovery populations; however, these effects are generally indirect in nature and challenging to quantify.

To better conceptualize the threats that recovery partners can influence, and as a result directly affect the status of this species, a simple model was constructed to inform the Conservation Efforts Database for LCT (CED:LCT) and this status review (Figure 4). Generally, recovery partners have the ability and authority to implement actions addressing habitat loss and fragmentation, habitat degradation, and non-native trout presence, especially on public lands. Thus, monitoring data related to those threats collected in the past, but not fully analyzed, are being collated and analyzed. However, these data are spatially and temporally disparate and/or rare and determining cause, trend, or even current condition using them has not been possible. In response, science-based core teams consisting of agency personnel and experts in the respective subjects were formed and funded to develop more rigorous and realistic monitoring and tracking approaches for the data most related to these threats (*e.g.*, habitat condition and trend, population demography and genetic health).

The new habitat monitoring program being developed will better assess the condition of LCT habitats and track changes to them through time. It will accomplish this by leveraging technology (*e.g.*, remote sensing, aerial photography) and simplifying the on-the-ground sampling approach. The baseline will be completed and integrated into the CED:LCT by December 2024. The effects of conservation actions have not been tracked well for LCT in the past, but will be *via* the CED:LCT starting as early as April 2023. Although significant progress has occurred to better capture and analyze data that directly or indirectly affect the resiliency of LCT populations, this resource is currently unavailable. Thus, the analysis in this review focused on the resiliency metrics described above as they are a direct measurement of LCT population resiliency. This review did not attempt to incorporate the disparate and indirect data sets (*e.g.*, non-native fish presence/absence, habitat, climate, or conservation actions data) into a more complicated analysis to better explain causation. It is important to note that integrating those data sources would not have altered the results/conclusions provided in this review because the threats and conservation actions have already acted on the populations and are likely reflected in the data used unless they have occurred only very recently. Where qualitative conservation action, habitat conditions/trend, and/or non-native fish presence data were available, they were used to help explain patterns in the resiliency metrics. If other institutional knowledge or expert opinion existed to help explain a pattern in the resiliency data, that information was also captured. The pending SSA for LCT will use the tools described above to better assess the effects of the threats and conservation actions, which will then be used to inform the next Status Review for LCT.

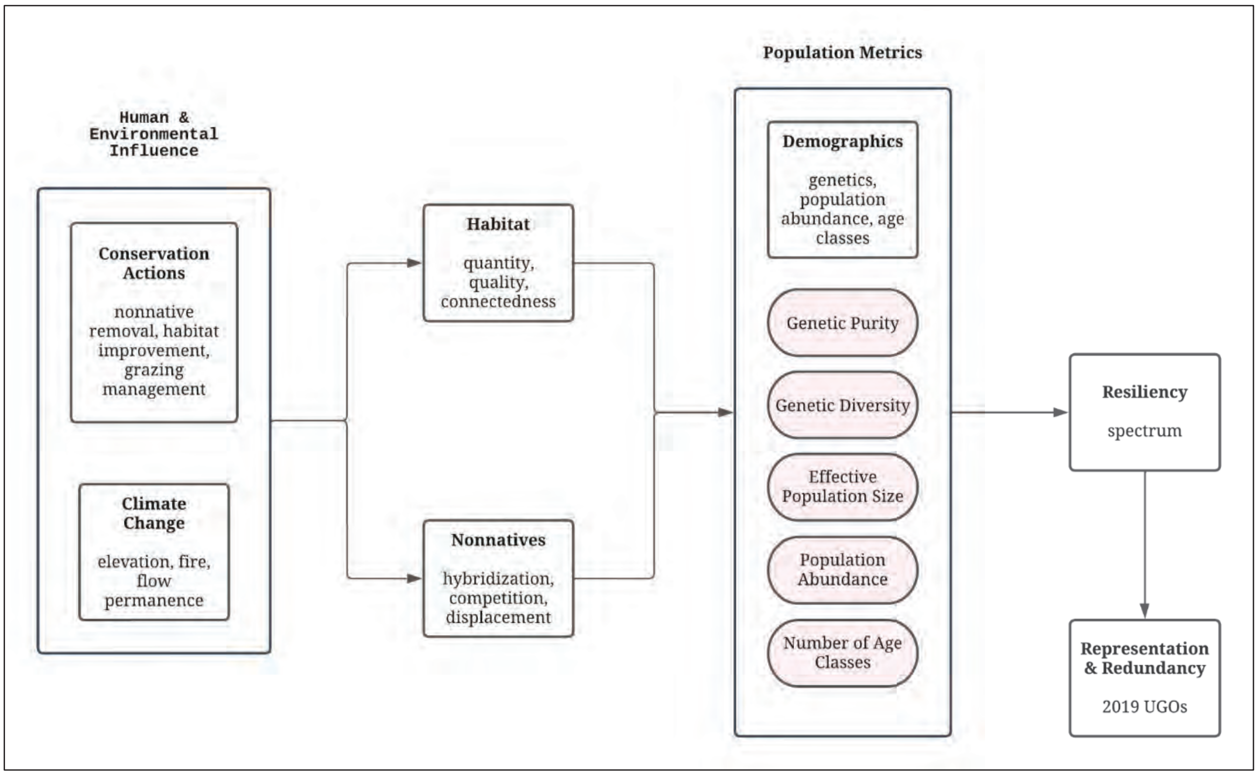


**Figure 4.** Conceptual model used to analyze resiliency in this review and inform the Conservation Efforts Database for LCT.

Recovery Criteria

We have learned much about the biology, populations status, and threats to LCT since the 1995 Recovery Plan was written. In response, recovery partners developed the Updated Goals and Objectives for the Conservation of LCT (2019 UGOs). This plan was fully endorsed at all levels of Federal, State, Tribal, NGO, and local agencies responsible for, or involved in, the recovery of LCT through the established governance structure. This document now guides the conservation of LCT until a formal recovery plan revision occurs. In short, the updated goals and objectives in the 2019 UGOs are based on the 3-R's framework (Appendix B: Technical Methods) and can be found in the LMU write-ups (Appendix C: Technical Results).

## III. RESULTS

This section summarizes all available and applicable population-level resiliency data that has been ranked using the metrics described above (Table 1; Table 2; and fully in Appendix B: Technical Methods and Appendix C: Technical Results). It also attempts to crosswalk expert opinion, historical documents/information, current threats, and next steps, where applicable. Each LMU was individually analyzed, except for the Humboldt Management Unit, which was analyzed at both the LMU level and then further evaluated at the hydrologic unit level due to its large geographic size. Representation and Redundancy were addressed as they relate to the 2019 UGOs; however, more emphasis was placed on population-level metrics and ranks, as they directly relate to the updated objectives. The threats-based objectives in the 2019 UGOs were qualitatively addressed at this time because consistent and recent data related to these objectives were not available rangewide. Full results write-ups for each LMU can be found within Appendix C: Technical Results.

The 2019 UGOs recommends that 40 recovery populations would be adequate to recover LCT. A recovery population was defined as having genetically pure LCT, with multiple age classes from regular, natural recruitment, and enough individuals to sustain a robust population in perpetuity (*i.e.*, to count towards recovery, populations as evaluated here would require a "resilient" assignment). Of the 71 potential recovery populations analyzed in this review, 8 ranked as at risk of extirpation, 28 ranked as unlikely to be resilient, 30 ranked as potentially resilient, and 5 ranked as likely resilient (Table 2). Though more robust genetic sampling is needed to truly resolve some of the genetic metrics, most populations, regardless of abundance, had moderately low to low genetic diversity and effective population size scores. For example, only 18 populations had moderate to moderately high scores with almost 75 percent (n=51) having effective population sizes below the consensus minimum of 50 needed to avoid inbreeding depression in the short term. The other metrics varied more across populations, however, with 29 populations having fewer than 3 age classes present (excluding young of year), 41 fewer than 1,000 fish, and at least 18 having some level of hybridization concern. More refined reasoning related to why potential LCT recovery populations grouped within specific categories are described better below and fully in Appendix C: Technical Results.

<u>Resilient Populations</u>

Only 5 of the 71 potential LCT recovery populations ranked as resilient based on high scores in most categories (Table 2). In general, these populations exist within larger, interconnected systems, likely allowing them to maintain higher demographic and genetic health metrics through time. Two additional populations also ranked as a resilient but are currently reliant on stocking operations by the Lahontan National Fish Hatchery (LNFH) to maintain demographic and genetic health metrics, so they were recategorized as potentially resilient at this time. The LNFH supplements these populations as part of their ongoing efforts to reintroduce LCT into the historically occupied lake habitat in the Pyramid-Truckee and Tahoe LMUs; more information

**Table 2.** Results table of potential LCT recovery population resiliency scores by metric. Five demographic (Abundance (N) and Age Class Structure) and genetic health (Genetic Diversity (Div), Hybridization Status (Hyb), and Effective Population Size ($N_e$)) metrics were collated and categorized using a simple scale, where 0 is poor/low and 4 is better/high; those scores were then averaged to produce a "resiliency" score (*i.e.*, Data Score), where 0–0.9 was generally considered *at risk of extirpation*, 1–1.9 *unlikely to be resilient*, 2–2.9 *potentially resilient*, and 3–4 *resilient*. The Data Scores were then reviewed by experts to ensure they were consistent with their assessments and recategorized as necessary (occurred most often when populations were straddling categories) to produce a Final Ranking. To fulfil an updated objective from the 2019 UGOs, an LCT population must be considered/ranked as likely resilient. See Appendix C: Technical Results for full description and important details.

| Management Unit | Population Name | $N_e$ score | Div Score | Hyb score | N Score | Age Class Score | Data Score | Final Ranking |
|---|---|---|---|---|---|---|---|---|
| Carson | Golden Canyon Creek | 0 | 2 | 4 | 1 | 4 | 2.2 | Unlikely to be resilient |
| Carson | Murray Canyon Creek | 0 | 2 | 4 | 1 | 3 | 2.0 | Unlikely to be resilient |
| Carson | Upper EF Carson / Golden Canyon | 0 | 2 | 4 | 1 | 4 | 2.2 | Unlikely to be resilient |
| Carson | Poison Flat Creek | 0 | 3 | 4 | 1 | 3 | 2.2 | Unlikely to be resilient |
| Humboldt/Little | Long Canyon Creek | 0 | 2 | 1 | 1 | 3 | 1.4 | Unlikely to be resilient |
| Humboldt/Little | Indian/SF Indian Creek | 0 | 1 | 4 | 3 | 3 | 2.2 | Potentially resilient |
| Humboldt/Little | Abel Creek | 1 | 2 | 4 | 2 | 3 | 2.4 | Potentially resilient |
| Humboldt/Little | South Fork Little Humboldt River Complex | 1 | 2 | 2 | 4 | 4 | 2.6 | Potentially resilient |
| Humboldt/North Fork | California Creek | 0 | 0 | 0 | 0 | 0 | 0.0 | At risk of extirpation |
| Humboldt/North Fork | Winters Creek | 0 | 0 | 0 | 0 | 0 | 0.0 | At risk of extirpation |
| Humboldt/North Fork | North Fork Humboldt River Complex | 0 | 3 | 3 | 4 | 3 | 2.6 | Potentially resilient |
| Humboldt/North Fork | Pratt Creek | 1 | 3 | 3 | 4 | 2 | 2.6 | Potentially resilient |
| Humboldt/North Fork | Foreman Creek | 1 | 4 | 4 | 1 | 3 | 2.6 | Potentially resilient |
| Humboldt/North Fork | Gance Creek | 1 | 3 | 4 | 4 | 2 | 2.8 | Potentially resilient |
| Humboldt/Pine | Birch Creek | 0 | 1 | 4 | 0 | 1 | 1.2 | Unlikely to be resilient |
| Humboldt/Pine | Pete Hanson Creek | 0 | 1 | 4 | 3 | 4 | 2.4 | Potentially resilient |
| Humboldt/Rock | Frazer Creek | 0 | 2 | 4 | 3 | 4 | 2.6 | Potentially resilient |
| Humboldt/Rock | Rock Creek Complex | 1 | 2 | 4 | 3 | 3 | 2.6 | Potentially resilient |
| Humboldt/Rock | Willow Creek Complex and Reservoir | 1 | 2 | 4 | 3 | 4 | 2.8 | Potentially resilient |
| Humboldt/South Fork | McCutcheon Creek | 0 | 0 | 0 | 0 | 0 | 0.0 | At risk of extirpation |
| Humboldt/South Fork | Welch Creek | 0 | 0 | 1 | 0 | 0 | 0.2 | At risk of extirpation |
| Humboldt/South Fork | Green Mountain Creek | 0 | 1 | 4 | 0 | 0 | 1.0 | At risk of extirpation |

| Management Unit | Population Name | $N_e$ score | Div Score | Hyb score | N Score | Age Class Score | Data Score | Final Ranking |
|---|---|---|---|---|---|---|---|---|
| Humboldt/South Fork | Dixie Creek | 0 | 2 | 4 | 0 | 0 | 1.2 | Unlikely to be resilient |
| Humboldt/South Fork | Smith Creek Complex | 1 | 1 | 3 | 2 | 1 | 1.6 | Unlikely to be resilient |
| Humboldt/South Fork | Brown Creek | 1 | 1 | 4 | 1 | 2 | 1.8 | Potentially resilient |
| Humboldt/South Fork | Lee Creek | 0 | 4 | 4 | 1 | 2 | 2.2 | Unlikely to be resilient |
| Humboldt/South Fork | Long Canyon Complex | 2 | 1 | 4 | 3 | 3 | 2.6 | Potentially resilient |
| Humboldt/South Fork | Pearl Creek | 1 | 3 | 4 | 3 | 4 | 3.0 | Likely resilient |
| Humboldt/Upper | Second Boulder Creek | 0 | 3 | 2 | 0 | 2 | 1.4 | Unlikely to be resilient |
| Humboldt/Upper | Currant Creek | 0 | 1 | 4 | 0 | 3 | 1.6 | Unlikely to be resilient |
| Humboldt/Upper | Sherman Creek | 0 | 1 | 4 | 2 | 1 | 1.6 | Unlikely to be resilient |
| Humboldt/Upper | Wildcat Creek | 0 | 2 | 4 | 0 | 2 | 1.6 | Unlikely to be resilient |
| Humboldt/Upper | North Fork Cold Creek | 0 | 1 | 4 | 4 | 2 | 2.2 | Potentially resilient |
| Humboldt/Upper | Jackstone Creek | 0 | 2 | 4 | 4 | 2 | 2.4 | Potentially resilient |
| Humboldt/Upper | Fourth Boulder Creek | 0 | 3 | 4 | 4 | 2 | 2.6 | Potentially resilient |
| Humboldt/Upper | T/Draw Creeks | 1 | 3 | 4 | 4 | 1 | 2.6 | Potentially resilient |
| Humboldt/Upper | Marys River Complex | 0 | 3 | 4 | 4 | 4 | 3.0 | Likely resilient |
| Humboldt/Upper | Maggie Creek Complex | 1 | 4 | 4 | 4 | 4 | 3.4 | Likely resilient |
| Independence | Independence Lake and Creek | 1 | 3 | 2 | 3 | 4 | 2.6 | Potentially resilient |
| Pyramid–Truckee | Pole Creek | 0 | 3 | 4 | 2 | 3 | 2.4 | Unlikely to be resilient |
| Pyramid–Truckee | Pyramid Lake and Truckee River | 2 | 3 | 4 | 4 | 4 | 3.4 | Potentially resilient |
| Quinn | Eightmile Creek | 0 | 1 | 2 | 0 | 0 | 0.6 | At risk of extirpation |
| Quinn | Crowley Creek | 0 | 1 | 3 | 1 | 2 | 1.4 | Unlikely to be resilient |
| Quinn | Falls Canyon Creek | 0 | 1 | 2 | 1 | 4 | 1.6 | Unlikely to be resilient |
| Quinn | Jackson Creek | 0 | 1 | 2 | 2 | 3 | 1.6 | Unlikely to be resilient |
| Quinn | Threemile Creek | 0 | 1 | 3 | 1 | 3 | 1.6 | Unlikely to be resilient |
| Quinn | Washburn Creek | 0 | 1 | 4 | 1 | 2 | 1.6 | Unlikely to be resilient |
| Quinn | Andorno Creek | 0 | 1 | 3 | 2 | 4 | 2.0 | Unlikely to be resilient |
| Quinn | Sage, Line, Corral Creeks | 0 | 1 | 3 | 2 | 4 | 2.0 | Potentially resilient |
| Quinn | Colman Creek | 0 | 1 | 4 | 4 | 2 | 2.2 | Potentially resilient |
| Quinn | Battle Creek | 0 | 1 | 4 | 3 | 4 | 2.4 | Potentially resilient |

| Management Unit | Population Name | $N_e$ score | Div Score | Hyb score | N Score | Age Class Score | Data Score | Final Ranking |
|---|---|---|---|---|---|---|---|---|
| Reese | Marysville Creek | 0 | 1 | 4 | 1 | 0 | 1.2 | Unlikely to be resilient |
| Reese | Crane Canyon Creek | 0 | 1 | 4 | 1 | 1 | 1.4 | Unlikely to be resilient |
| Reese | Mohawk Creek | 0 | 1 | 4 | 1 | 1 | 1.4 | Unlikely to be resilient |
| Reese | Tierney Creek | 0 | 1 | 4 | 0 | 1 | 1.2 | At risk of extirpation |
| Reese | Washington Creek | 0 | 1 | 4 | 1 | 2 | 1.6 | Unlikely to be resilient |
| Reese | Cottonwood and San Juan Creeks | 0 | 1 | 4 | 2 | 4 | 2.2 | Potentially resilient |
| Summit | Snow Creek | 0 | 1 | 4 | 1 | 3 | 1.8 | Unlikely to be resilient |
| Summit | Summit Lake Complex | 2 | 3 | 4 | 4 | 4 | 3.4 | Likely resilient |
| Tahoe | Upper Truckee River (Meiss Meadow) | 2 | 3 | 4 | 4 | 3 | 3.2 | Likely resilient |
| Tahoe | Fallen Leaf Lake | 2 | 3 | 4 | 4 | 4 | 3.4 | Potentially resilient |
| Tahoe | Lake Tahoe | no data | no data | no data | no data | no data | no data | NA |
| Walker | Cottonwood Creek | 0 | 2 | 4 | 1 | 3 | 2.0 | Unlikely to be resilient |
| Walker | Murphy Creek | 0 | 2 | 4 | 1 | 4 | 2.2 | Unlikely to be resilient |
| Walker | By–Day Creek | 0 | 2 | 4 | 2 | 3 | 2.2 | Unlikely to be resilient |
| Walker | Silver Creek | 0 | 2 | 4 | 2 | 3 | 2.2 | Potentially resilient |
| Walker | Slinkard Creek | 0 | 2 | 4 | 2 | 4 | 2.4 | Potentially resilient |
| Walker | Wolf Creek | 0 | 2 | 4 | 3 | 4 | 2.6 | Potentially resilient |
| Walker | Mill Creek | 0 | 2 | 4 | 4 | 4 | 2.8 | Potentially resilient |
| Willow–Whitehorse | Antelope Creek | 0 | 0 | 4 | 0 | 0 | 0.8 | At risk of extirpation |
| Willow–Whitehorse | Whitehorse Creek Complex | 0 | 2 | 4 | 4 | 4 | 2.8 | Potentially resilient |
| Willow–Whitehorse | Willow Creek | 0 | 2 | 4 | 4 | 4 | 2.8 | Potentially resilient |

about progress related to these potential recovery populations can be found in Appendix C: Technical Results. In addition, at least 10 of the potentially resilient populations could become resilient in the next 5–10 years by meaningfully managing the threats within those populations (see Table 3 for some specific examples and Appendix C: Technical Results for population-by-population write-ups). Moreover, several of these populations were on the high end of the potentially resilient category and can likely become resilient soon through simple management actions, such as assisted or facilitated migration (*e.g.*, Mill, Willow, Whitehorse Creeks).

Potentially Resilient Populations

Thirty of the 71 analyzed LCT populations ranked as potentially resilient (Table 2). These potential LCT recovery populations exist within a variety of habitat types and sizes, with variable threats, making it challenging to generalize them. However, about 1/3 of the populations ranked in this category are likely to remain in this category through time due to limited management options. The other approximately 2/3 could become more resilient with improved management; as mentioned above, about 10 of these populations could be resilient in the next 5–10 years by meaningfully managing the threats within them, some through simple actions like improved genetics management and localized habitat restoration (see Table 3 for some specific examples and Appendix C: Technical Results for population-by-population write-ups). This would lead to a significant improvement in the status of LCT, but not recovery. The remaining 10 or so populations could be resilient in the future, but due to the complex nature and large size of most of them, it is expected that securing them would take more than 10–20 years (*e.g.*, Long Canyon Creek, McDermitt Creek, Pyramid Lake).

In general, low to moderate genetic health metrics were the contributing factors to many populations ranking in this category. These low genetic health metrics indicate that smaller, isolated populations, and likely even some of the larger ones, are experiencing repeated stochastic events (bottleneck-expansion-bottleneck) that lead to reductions in genetic diversity (Neville *et al.* 2009, Whiteley *et al.* 2010, Whiteley *et al.* 2013). This ultimately leads to the maintenance of only a small portion of the original diversity of that population, regardless of how many individuals are present. Lastly, improving population-level monitoring and management over the coming years through the development of the LCT GMP and associated documents will refine estimates of population resiliency and better direct conservation actions to improve recovery outcomes.

Unlikely to be Resilient

Twenty-eight potential LCT recovery populations ranked as unlikely to be resilient in this review (Table 2). In general, these populations had low rankings in all but hybridization status and age-class structure, although this was not always the case (*e.g.*, Lee Creek, Pole Creek, Jackson Creek). These populations are generally above barriers in small, headwater streams without realistic management options to improve their status. However, reconnecting them to other small, isolated populations (*e.g.*, Murray Canyon, Golden Canyon, and Poison Flat Creeks to the Upper E.F. Carson River) physically or *via* assisted migration (*e.g.*, Andorno and Falls Canyon along the westside of the Santa Rosa Range) may be possible future conservation actions. This would result in larger, interconnected populations that would likely have improved demographic and genetic health metrics. However, it will be important to prioritize where, how, and when to work to best conserve the species. These larger-scale projects generally take 10 to 20 years to complete, and more are needed to recover this species.

**Table 3.** Example of ongoing projects that are contributing to LCT recovery and that should be included in future Short-Term Action Plans for the different LMU's.

| Management Unit | Population Name | UGOs Objective(s) | Project Description |
|---|---|---|---|
| Humboldt/Little | Abel (and Stonehouse) Creek | HU 1, 5 | YY brook trout study |
| Humboldt/Little | South Fork Little Humboldt River | HU 2, 4 | Grazing management, infrastructure improvements, and habitat restoration |
| Humboldt/North Fork | North Fork Humboldt River | HU 1, 6 | LCT reintroduction, barrier study, and habitat restoration |
| Humboldt/Rock | Willow Creek Complex and Reservoir | HU 1, 8 | Non-native trout removal/management |
| Humboldt/Rock | Rock Creek, Frazer Creek | HU 2, 9 | Grazing management, infrastructure improvements, and habitat restoration |
| Humboldt/Upper | Marys River Complex | HU 1, 2, 12 | Non-native trout/grazing management, infrastructure improvements, barrier study, and habitat restoration |
| Quinn | McDermitt Creek Complex | QU 1, 3 | Non-native trout removal/management and LCT reintroduction |
| Summit | Summit Lake Complex | RU 2 | Non-native plant management and habitat restoration |
| Walker | Slinkard Creek | WU 1, 3 | Non-native trout removal, barrier retrofit, and genetic management |
| Walker | Silver Creek | WU 1, 3 | Non-native trout removal |
| Walker | Mill Creek | WU 1, 3 | Genetic management |
| Willow–Whitehorse | Whitehorse Creek Complex and Willow Creek | WWU 2, 3, 4 | Habitat restoration to mitigate existing headcut and genetics management |
| Independence | Independence Lake and Creek | IU 1, 2 | Non-native trout removal and lower creek barrier installation |
| Pyramid–Truckee | Pyramid Lake and Truckee River | PTU 1, 3 | LCT reintroduction, fish passage projects, and non-native trout management |
| Tahoe | Upper Truckee River (Meiss Meadow) | TU 1, 2, 3 | Non–native trout removal/management |
| Tahoe | Lake Tahoe | TU 1, 2 | LCT management and research |

At Risk of Extirpation

Eight of the 71 potential LCT recovery populations ranked as at risk of extirpation (Table 2). These populations are mostly located in small stream systems, which dry to a trickle annually and individuals survive in only a few pool refuges located at/near spring heads; thus, the population size is reduced to a handful of individuals most years, resulting in very low demographic and genetic metrics. Although more water is present within two of these populations (Green Mountain and Tierney Creeks), LCT have been largely replaced by non-native brook trout and there are no longer realistic management options to conserve them. Experts agree that these populations are likely to be extirpated within the next 5–10 years (if they have not been already). If possible, individuals from these populations should be genetically sampled, and if pure LCT, moved into neighboring LCT populations that are more likely to persist in the longer-term (based on guidance from the pending LCT GMP).

Discussion

The results of this review indicate that the goal of resiliency has not yet been achieved for LCT. Of the 71 potential LCT recovery populations analyzed here, only 5 were categorized as resilient and count towards the recommended 40 populations to recover the species (Table 4/Figure 5). Furthermore, each of those populations is still experiencing some of level of threat from non-native trout and/or habitat degradation, and thus the threats-based objectives within the 2019 UGOs have not been completed yet (see Appendix C: Technical Results). Of the 30 potentially resilient LCT populations, at least 10 of them could become resilient in the next 5–10 years by employing well known and feasible conservation actions; moreover, an additional 10 or so could become resilient over the next 10–20 years with significant conservation efforts (some are already in progress). Of the remaining 36 potential recovery populations that ranked as not likely to be resilient or at risk of extirpation, another 10 or so of those could become resilient over the next 10–20 years, although these populations would require even more substantial conservation efforts (*e.g.*, reconnecting steams together).

The goals of rangewide representation and redundancy have not been met at this time either. Representation has only been partially fulfilled by maintaining, albeit at various levels of resiliency, populations that display variable life-history strategies and contain what is left of the genetic legacy and diversity of this species throughout a variety of ecological and geographical settings within LCT's historical range. Of the 10 LMUs, only the Summit Management Unit has completed its updated objectives; however, the Summit Lake LCT recovery population is not without contemporary threats that need to be managed before that population can reach its full potential. Of the other LMUs, the Tahoe and Humboldt Management Units contain the remaining 4 resilient LCT recovery populations; although these populations appear resilient today, they together do not meet the definition of redundancy defined in the 2019 UGOs.

It is clear that some level of representation, redundancy, and resiliency of LCT is present on the landscape today; for example, there are 5 resilient populations and at least 10 others that could be resilient with improved management and the application of relatively simple conservation actions. Furthermore, there are an additional 20 or so populations that could be brought into higher states of resiliency through concerted conservation efforts over the coming decades. The opportunities to manage the threats to LCT and improve its status relatively quickly are plentiful; it is also well-known how to address these threats, with straight-forward and well-accepted solutions. Furthermore, interagency relationships and collaboration with stakeholders and rightsholders are improving, which should enhance results as more resources are dedicated to this effort. These improved relationships should also allow for a more transparent and effective prioritization process soon, which would further improve conservation outcomes. Therefore, it is possible and logical to use the information in this review, and the current momentum, to reverse the declining trend LCT has been experiencing over the last several decades and begin to improve its status.

**Table 4.** Summary of population resiliency assessment, where all available demographic and genetic health data for each of the 71 LCT populations managed for recovery purposes were summarized, analyzed, and ranked.

| Resiliency Category | Number of Populations Assigned (N=71) |
|---|---|
| Likely Resilient | 5 |
| Potentially Resilient | 30 |
| Unlikely to be Resilient | 28 |
| At risk of Extirpation | 8 |

Brief Rationale and Conclusions

Overall, the status of this species continues to decline. Yet, there is no clear indication that reclassification is necessary at this time. With 71 LCT populations managed for recovery purposes spread throughout LCT's historical range (as well as several additional populations outside the historical range), there is clearly some level of representation, redundancy, and resiliency present indicating that LCT is not in currently in danger of extinction. Moreover, there are an abundance of opportunities to reverse LCT's declining trend, with at least 10 populations that could potentially become resilient populations in the next 5–10 years with improved population and land management (see Table 3 for some specific information). However, the low genetic health metrics of many of the populations indicates that they have experienced some of deleterious effects of population isolation; to ensure these populations can become resilient in the future they will require active genetic management. Examples of possible management actions include creating gene flow between isolated populations (assisting or facilitating migration) that would otherwise be connected or improving detection and removal capabilities of non-native or hybridized trout from potential recovery populations before widespread introgression occurs.

One of the most important steps conservation partners can take from a genetic health and long-term persistence standpoint is to complete a full genetic assessment to inform the LCT GMP. This, in combination with the habitat data that is being collected about current and future (through the integration of several forecasting models) habitat conditions, should allow recovery partners to better prioritize future recovery efforts. While this prioritization process is occurring over the next several years, ongoing conservation work should continue for high-priority populations identified in Table 3 above and/or discussed in Appendix C: Technical Results. When the prioritization process is completed, it will then be necessary to create a more robust, multi-species, effort to restore ecosystem processes within those climate-resilient landscapes to allow for truly effective, sustainable progress to be made. This will require the involvement of all relevant rightsholders/stakeholders and an open and transparent process.

In conclusion, the threats to LCT continue to cause a decline in its status through time primarily due to threats from non-native trout and habitat degradation that continue to impact most resilient and potentially resilient populations. To reverse these trends, there is still much work to do. There are at least 10 populations that could become resilient over the next 5–10 years if the threats are properly managed; this is where recovery partners should focus their efforts while developing a prioritization process over the coming years. With the completion of planned and ongoing recovery projects, and the initiation of a focused effort by recovery partners to prioritize

LCT conservation, this decline could be stabilized and even reversed prior to the next Status Review. To move in the right direction, it is critical that the actions discussed in the results above (and further articulated in the recommendations below) are completed in the coming years.

**Recommended Classification**

___ Downlist to Threatened
___ Uplist to Endangered
___ Delist (*Indicate reasons for delisting per 50 CFR 424.11*)
  ___ *Extinction*
  ___ *Recovery*
  ___ *Original data for classification in error*
_X_ No change is needed

**Field Supervisor (Acting), Reno Fish and Wildlife Service Office**

Approve DANIEL COX Digitally signed by DANIEL COX Date: 2023.02.23 15:43:54 -08'00' Date ________________

**Assistant Regional Director, Ecological Services, Region 8**

Approve MICHAEL SENN Digitally signed by MICHAEL SENN Date: 2023.02.24 14:59:23 -08'00' Date ________________

## IV. RECOMMENDATIONS FOR FUTURE ACTIONS

Based on the information presented in this review, there is a clear need to use decision support tools (*e.g.*, CED:LCT, R.A.D. Framework) to assist implementation planning of short- (next 5–10 years) and longer-term (20 years) priorities to focus conservation actions on the populations that are most likely to persist through expected climatic changes and meet the needs for recovery. In the past, available resources have generally been spread too thin on 70+ populations in an unstructured fashion. Resources need to be focused on resilient and potentially resilient LCT populations that are the most likely to persist through time. This will require a better understanding of not only the genetic health and population management options, but also current habitat conditions and where climate-resilient habitat exists throughout the historical range of LCT. The priority leading up to the next Status Review should be to prioritize and implement recovery efforts based on restoration potential and climate-resiliency of habitats and the genetic and demographic sustainability of existing populations.

The Service recommends that the following conservation actions (in addition to those mentioned in the Table 3) are completed over the next five years to improve the success of recovery efforts moving forward:

1) Complete development of (or update existing) Short-Term Action Plans (in 2023) for each LMU based on recommendations presented above (see Table 3 as a starting point for near-term actions);
    - These documents will be collaboratively developed, formally codifying responsibility of specific actions within each of the recovery priorities developed within the Short-Term Actions Plans, which will help increase efficiency and effectiveness of these priorities in the short-term.

2) Complete the LCT Genetics Management Plan (GMP) in 2024;
    - This plan will include data-derived recommendations to begin addressing the genetics health issues present within almost all LCT populations on the landscape;
    - This plan will provide population monitoring and management suggestions to increase efficiency and consistency across the historical range.

3) Complete the LCT Habitat Monitoring Program and fund a second round of sampling;
    - The habitat monitoring program will provide the first comprehensive assessment of habitat conditions LCT populations are experiencing range wide by 2024;
    - Commitment by applicable recovery partners to develop and implement a realistic and affordable long-term sampling program that begins to establish temporal trends; in combination with trend information collected *via* GIS/drones, recovery partners can then determine where to place resources in the future to maximize restoration outcomes.

4) Fully fund and complete the Conservations Efforts Database for LCT (CED:LCT);
    - A centralized database for LCT has not existed previously, making it difficult to analyze data range wide and make broad inferences of the status of the species. This tool will allow all stakeholders to see LCT recovery progress by tracking data related to population resiliency (the demographic and genetic metrics analyzed here), habitat condition and trend (*via* the LCT Habitat Core Team's efforts), conservation actions (from all recovery partners), and non-native fish presence/abundance (*via* genetics and other methods);
    - This effort is only partially funded; approximately $300,000 is needed to finish Phase 2 (making the CED:LCT fully operational) and to link it to other databases and tools (Phase 3; 2023-2025).

5) Update the Multiple Population Viability Tool (MPVA) for LCT and link to the CED:LCT;
    - The existing MPVA for LCT is an important tool to forecast the extinction probability of existing populations and needs to be reformatted to create a cheaper, easier way to regularly update and link this tool to the CED:LCT; this

endeavor is also crucial for feeding a decision-support tool to allow recovery partners to become strategic regarding future LCT recovery priorities.

6) Develop a Future Scenarios/Decision Support Tool using the CED:LCT and the MPVA;
   - Use the newly developed database and updated MPVA resources to create and feed a future scenarios analysis that can inform a decision-support tool; without these, LCT recovery will not move forward fast enough to stabilize and reverse the declining trend in its status.

7) Complete a Species Status Assessment to inform the next Status Review; and
   - Fully synthesize the best available science into an SSA for LCT; use the information within it to inform the next Status Review.

8) Update the 2019 UGOs in response to the new information presented within the SSA/next Status Review.
   - Update the 2019 UGOs and formalize through a Recovery Plan revision; reformat and update the Short-Term Action Plans developed in response to this review to fit the recommended Recovery Implementation Strategy (RIS) format.

By completing these tasks, as well as the on-the-ground priorities discussed above, LCT recovery partners will have a clearer vision for recovery. Additionally, clarifying roles will ensure partners understand their responsibility in achieving the updated objectives outlined in the 2019 UGOs. Based on the results presented here, urgency is needed to conserve and recover the species. It is vital that all stakeholders involved in LCT recovery commit to and complete the future actions recommended above, and the priority projects described in Table 3, to stabilize and ultimately reverse the long-occurring declining trend of the status of LCT.

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# APPENDIX A: LIST OF RECOVERY PARTNERS

## MOG/CC Charter Agencies

Bureau of Land Management, California and Nevada

California Department of Fish and Wildlife

Humboldt–Toiyabe National Forest, U.S. Forest Service

Lake Tahoe Basin Management Unit, U.S. Forest Service

Nevada Department of Wildlife

Oregon Department of Fish and Wildlife

Pyramid Lake Paiute Tribe

Summit Lake Paiute Tribe

Tahoe National Forest, U.S. Forest Service

Tahoe Regional Planning Agency

U.S. Army Corps of Engineers

U.S. Bureau of Reclamation

U.S. Fish and Wildlife Service, Ecological Services and Lahontan National Fish Hatchery

U.S. Geological Survey

Walker River Paiute Tribe

Washoe Tribe of Nevada and California

## Additional Recovery Partners

California Trout

Desert Research Institute

Great Basin Institute

Natural Resources Conservation Service

Nevada Cattlemen’s Association

Nevada Department of Conservation and Natural Resources

Nevada Gold Corporation

The Nature Conservancy

Trout Unlimited

University of California, Davis

University of Nevada, Reno

Utah State University

Western Rivers Conservancy

# APPENDIX B: TECHNICAL METHODS

## Representation and Redundancy

Representation is a species' ability to adapt to a changing environment over time. Redundancy is a species' ability to spread risk throughout its range and ensure its adaptive capacity is maintained despite catastrophic events. The 2019 UGOs define representation and redundancy goals for LCT recovery:

> ***Representation:*** *conserve the genetic and behavioral (i.e., variable life–history strategies / characteristics) diversity of LCT by ensuring that it is present within the variety of ecological and geographic settings throughout its historical range.*
>
> ***Redundancy:*** *ensure that an adequate number and distribution of LCT populations are present throughout its historical range so that catastrophic events do not diminish the adaptive capacity of LCT.*

LCT should contain the adaptive capacity necessary to persist into the future when all the updated conservation objectives in the 2019 UGOs are fulfilled. These updated objectives were designed to ensure the preservation of the genetic and behavioral/life-history diversity of the species in ecologically and geographically representative habitat throughout its historical range. Therefore, when all spatially explicit objectives are met range wide, representation will be accomplished. Redundancy is accomplished at the LMU-level, where it can be assessed through the percentage (or number) of updated objectives that have been met at the time of this review for each LMU. Both the redundancy and representation goals are relatively easy to measure and track. However, measuring and assessing progress towards the 3$^{rd}$ goal, resiliency, is more challenging due to the complex nature of measuring population-level metrics through time and making inferences; however, as more resiliency data are collected in the future and compared to this baseline analysis, the status review process will become simpler.

## Resiliency

Resiliency is a species' ability to withstand demographic and environmental stochasticity at the population level. The desired elements of a resilient LCT recovery population are that it contains enough genetically pure individuals that are sufficiently distributed throughout a large enough habitat fragment to withstand stochastic events and that it is maintained by natural reproduction resulting in regular recruitment. A population meeting this definition would have several age-classes present, be able to maintain healthy demographic and genetic metrics through time and would contain genetically pure LCT. The term "genetically pure" in this context, and the above document, refers to a potential LCT recovery population that does not show introgressive hybridization with the closely related *Oncorhynchus mykiss* taxa or other *O. clarkii* taxonomic units (*e.g.*, Yellowstone, Westslope, and Paiute Cutthroat Trout), though the detection and quantification of introgressive hybridization is sensitive to the genetic marker and statistical estimation methods used. In addition, and further explained below, populations that are known to have some level of introgressive hybridization with other taxa may still have significant conservation value since those populations still also contain LCT genetic information.

> ***Resiliency:*** *ensure that each LCT population used to meet the updated objectives contains an adequate number of individuals that are distributed throughout sufficient habitat so that they can withstand stochastic, population–level events over time.*

Resiliency was evaluated using a scoring matrix comprised of five metrics applied consistently across all LCT populations managed for recovery purposes (see Table 1 in review text above). In general, raw data for each metric were summarized using variable but appropriate methodologies (see detailed descriptions below) using a grade point average approach, which resulted in a score from zero to four. This sort of framework has been used in other recent SSA/5–Year Review efforts when similar types and amounts of data were available (*e.g.*, Dauwalter *et al.* 2017).

The metrics used in this review are well-recognized demographic and genetic health measurements and include: (1) population abundance, (2) number of age-classes, (3) effective population size, and (4) genetic diversity, and (5) hybridization status. Data were ranked on a scale from zero to four with zero being very low or absent and four being as high as reasonably possible. When data were not available, metrics were scored *via* expert opinion from field/technical staff intimately involved in the conservation of LCT. Lastly, the five scores were averaged to produce a population resiliency score between zero and four; in general, populations scoring above three were categorized as likely resilient, between two and three as potentially resilient, between one and two as unlikely to be resilient, and below one as at risk of extirpation.

<u>Genetic Resources Used to Evaluate Population Resiliency</u>

Rankings for genetic metrics were informed by several published studies (Hemstrom *et al.* 2022; Neville *et al.* 2016, Neville *et al.* 2006, Peacock and Dochtermann 2012, Peacock and Kirchoff 2004, Peacock *et al.* 2010), reports (*e.g.*, Peacock and Kirchoff 2007), or unpublished results from ongoing genetic assessment of LCT requested by state wildlife agencies in Nevada, California, and Oregon. These studies drew on collections from varied field sampling, ranging from targeted/designed sampling for specific research or needs, to semi-rotational ongoing interagency sampling for general monitoring. Thus, LCT data have not been collected in a systematic way through time, leading to somewhat sporadic temporal and spatial sampling and differing methods of sampling within populations based on purpose of the sampling effort. Nevertheless, field sampling for LCT has generally involved electrofishing age 1+ individuals across multiple (typically 3+) sections of each stream and/or across a broad distribution of occupancy to ensure representation of the genetic variability within each population and to attempt to avoid sibling groups.

The above studies employed different genetic markers as the technology has advanced over time; Neville *et al.* (2006) used a suite of microsatellite markers adapted from other species, while Neville *et al.* (2016) and the Peacock *et al.* work used a set of microsatellite markers developed specifically for LCT for evaluation of population genetic variability (Peacock *et al.* 2004), and in some cases employed additional markers that distinguish rainbow trout and different forms of other cutthroat trout for hybrid analysis (Ostberg and Rodriguez 2002, Pritchard *et al.* 2013). Hemstrom *et al.* (2022) relied on single nucleotide polymorphisms (SNPs) acquired through a baited Restriction site Associated DNA (RAD Capture, or RAPTURE, Ali *et al.* 2016, Kelson *et al.* 2019) sequencing approach to estimate both LCT population genetic variability and hybridization (the latter by comparison with sequences from rainbow trout and Yellowstone cutthroat trout, see more below). See associated publications or reports for details on genetic methods. Currently, there is a collaborative genetic analysis underway between several recovery partners and UC Davis, UN Reno, and Trout Unlimited to evaluate and compare potential LCT recovery populations. It is anticipated that the results of that new effort will be available in 2023–24. Additionally, a reference genome for *O. clarkii* is currently being developed *via* the California Conservation Genomics Project, which will aid in more accurate genetic mapping of Cutthroat Trout, and LCT in the future.

To evaluate the genetic metrics, estimates from each study were tabulated independently and, in some cases, translated directly into rankings (see Table 1 within review text above). Where multiple studies produced data for the same population(s), results were evaluated collectively and generally averaged when translating them into rankings. Overall, the different results from the different studies referenced in this review where quite consistent with each other for a given population, but where averages fell between categories other information was used to decide on the most appropriate overall categorical ranking. Factors that were considered when deciding between rankings included how recently the sample was collected, the sample size and purpose of sampling (as a gage of confidence in results, *e.g.*, for hybridization assessment), and any known stochastic/catastrophic event(s) and/or management activities that might alter the trajectory of a given metric (*e.g.*, expert opinion, persistent stream drying, on-going removal of non-native trout, wildfire).

### *Effective Population Size*

Effective population size ($N_e$) was estimated using several different approaches across studies for this review. Neville *et al.* 2006 used a maximum likelihood coalescent/genealogy-based approach implemented in the program MIGRATE (Beerli 2004, Beerli and Felsenstein 1999, Beerli and Felsenstein 2001), while Hemstrom et al. (2022) relied largely on a sibling reconstruction approach in the program COLONY (Jones and Wang 2010). The Peacock *et al.* studies used a linkage–disequilibrium method in NeEstimator (Peel *et al.* 2004, Waples and Do 2010). See each reference for specific details on assumptions, parameter values, etc. Regardless of the estimation approach, $N_e$ provides a valuable metric that can be useful in evaluating the relative risk of maladaptive processes occurring within the populations analyzed in this review. In fact, it is considered one of the most important metrics to evaluate in conservation due to its direct connection to deleterious genetic effects, such as inbreeding depression, and long-term evolutionary potential and viability (Frankham *et al.* 2014); as such, it is also a useful indicator of impacts to genetic diversity and health that populations may be suffering (or have suffered) due to various threats (Olah *et al.* 2021).

However, $N_e$ can be quite complex to define, measure, estimate, and interpret for various reasons. First, $N_e$ is only relevant to a defined, randomly mating unit, *i.e.*, a discrete “population”. Depending on conservation goals this can be interpreted at scales ranging from a localized sub-population up to an entire species where it is comprised of a single, well-mixed (panmictic) population (*e.g.*, many IUCN listings). For LCT, given the highly fragmented and isolated nature of the remaining populations, a global, species-level $N_e$ is not relevant. Previous estimations of $N_e$ have been done at the stream/local population scale, representing a degree of resolution that may not be entirely necessary for ESA considerations of extinction risk for the species but one that is relevant to understanding the potential sustainability of the local populations we currently consider the building blocks of recovery (*i.e.*, the updated conservation objectives are at the population-level). Next, $N_e$ can be calculated directly in a captive population with a known number of breeding individuals and known relative family sizes. However, in wild populations, like the ones included in this review, $N_e$ is inferred through various statistical methods using genetic marker data. In practice, this estimation in wild populations can be quite sensitive to the model assumptions and the genetic marker data used, sometimes yielding large confidence intervals.

Another issue with estimating $N_e$ is that even very low levels of gene flow or population substructure violate the assumption of a discrete panmictic population, with important influences on $N_e$ (generally causing downward bias; Jamieson and Allendorf 2012). Almost all LCT populations are indeed completely isolated, so adhere to this assumption, but some samples and estimates used here may be influenced by movement and/or substructure. Lastly, the theoretical assumption of discrete generations may affect estimations, which in many cases is known to be violated in nature, including in LCT populations. Because LCT field samples used here consisted of multiple age classes combined in a “population sample”, the resulting estimates are again likely biased downward, especially when employing a linkage disequilibrium approach, due to an overlapping cohorts mixing effect (Waples *et al.* 2014). However, as shown by Waples *et al.* 2014, the approximate degree of this bias can be estimated (and then corrected for as described below) using a ratio of Adult Lifespan (AL)/Generation Length (Gen) for a given species (though note this may vary across populations in reality). Adult lifespan is calculated as:

$$AL = w - a + 1$$

where w = maximum age and a = age at maturity. Based on previous age estimates from the above studies we assumed for stream form LCT a maximum age of seven and an age at maturity of three. Assuming a generation length (the mean age of parents) of four, we estimate an AL/Gen ratio of 5/4, or 1.2 (note another assumption of this adjustment is that the genetic sample includes representatives from every cohort, which may or may not be true). Figure 6 in Waples *et al.* (2014) suggests, then, our $N_e$ estimates may be approximately 70% or more of the true $N_e$ due to this cohort mixing effect on linkage disequilibrium. Additionally, $N_e$ estimates from Hemstrom *et al.* (2022) should be interpreted with caution due to small sample sizes, which were sufficient for sequenced-based estimates of genetic diversity but likely cause further (downward) bias in $N_e$ estimation (see Ackerman *et al.* 2017 as related to the sibship method in particular) - although in some cases here the sample LCT represented all fish captured after significant effort. To account for both types of generally downward bias, Hemstrom *et al.* (2022) doubled the $N_e$ estimates from their study (that is, assumed the estimated values may be biased quite low to be as much as 50% of the actual $N_e$). In the end, given the extremely low and comparable values across all studies synthesized here, including the previously published work using much larger sample sizes, this methods-conservative approach was employed with very little change in the actual ranking of the populations reviewed here.

$N_e$ estimates from the above studies (with values from Hemstrom *et al.* (2022) representing 2x the estimated $N_e$) were translated directly into categorical rankings (Table 1), with occasional adjustment as described above when multiple results were available but fell between categories. Because of generally low $N_e$ for all LCT populations in this review, the complexities of defining and measuring $N_e$ accurately must be acknowledged here; there is a clear need to consider a more concerted sampling effort, as well as potential opportunity for genetic management through assisted migration, in the future. Therefore, we generally interpreted $N_e$ results in a relative sense and as an indicator of concerning genetic impacts on populations that points to genetic management needs for many (sensu Jamieson and Allendorf 2012). An $N_e$ of 501 or greater was given a score of 4 (and was considered highly resilient), while we considered scores below 4 as relative rankings with 251–500 scoring a 3 (*e.g.*, resilient), 101–250 scoring a 2 (*e.g.*, potentially resilient), 51–100 scoring a 1 (*e.g.*, likely not resilient), and less than 50 or fewer scoring a 0 (*e.g.*, the least resilient). Truly isolated populations with these lower Nes are considered at risk and are expected to continue to lose genetic diversity in the future (Jamieson and Allendorf 2012). Although there is still healthy deliberation about how high $N_e$ needs to be for a population to be resilient, this scale is appropriate and supported by the science related to $N_e$ and population resiliency (Franklin *et al.* 2014, Jamieson and Allendorf 2012).

### *Genetic Diversity*

Because of the long use of microsatellite markers for LCT and an achieved comfortability with the meaning of actual values derived from them, estimates of observed and expected heterozygosity ($H_o$ and $H_e$) from the multiple studies using microsatellite loci were translated directly into the scoring matrix in Table 1. They were based on categories that captured the range of values observed across the LCT distribution in microsatellite work to date. Relatively High diversities (above 0.80) scored a 4, moderately high (0.65–0.79) a 3, moderate (0.40–0.64) a 2, moderately low to low (below 0.40) a 1; these categories also fit reasonably well with the quartile approach described in the next paragraph.

It was difficult to evaluate and compare the magnitude of sequence-based diversity in a similar fashion to the microsatellite data described above. Accordingly, while Hemstrom *et al.* (2022) did estimate $H_o$, as well as nucleotide diversity ($\pi$) and Tajima's and Waterson's theta ($\Theta_T$ and $\Theta_W$), instead of interpreting these directly as with microsatellites, results for each diversity metric were assigned quartile values to rank populations across the highest (score of 4) to lowest (score of 1) quartiles relative to each other; quartile values were then averaged across the metrics ($H_o$, $\pi$, $\Theta_T$, and $\Theta_W$) for a population-level quartile-based diversity assignment (with 4 being the highest, 3 and 2 moderately high and low, respectively, and 1 being the lowest score).

Where results were available from multiple studies, diversity metrics were compared/collated across those studies and translated into a 1–4 diversity value for each population, with microsatellite-based diversity values translated directly to the indicated score (Table 1) and sequence-based metrics translated based on their average quartile assignment. As with the above, where averaged results from different studies fell between categories, additional information about the population (*e.g.*, year of field collections, sample sizes, known active management) was evaluated to assign an ultimate diversity ranking.

It should be noted that actual values of $H_o$ and He in a population study are directly affected by the genetic marker system used, in that the rate of mutation and number of character states per locus varies (*e.g.*, microsatellites vs SNPs). Once again, these sorts of data are an important component of a population's story, but alone should be interpreted with caution due to the various issues that can increase the uncertainty of this type of information.

***Hybridization Status***

The hybridization status was estimated for each potential LCT recovery population using a variety of data from various studies. Genetic status related to the threat of hybridization and introgression should be interpreted cautiously here due to limited sampling available to evaluate this issue comprehensively at this time. That is, unless intensive field sampling was performed specifically to capture hybrids throughout a population's distribution, which has only occurred very rarely to date for LCT, sample sizes are too small and insufficient to detect hybridization or introgression even where it may exist. In the context of this review, hybridization status (*i.e.*, fractional ancestry) of the various LCT populations refers to introgressive hybridization with other *O. clarkii* taxonomic units and subspecies and the closely related *O. mykiss*. Statistical estimates of fractional ancestry of an individual can be sensitive to the actual samples, genetic markers, and statistical model assumptions used to derive estimates of "genetic purity" (or conversely, the amount of introgression within that individual).

Another important consideration is that the same population-level %LCT fractional ancestry value can be generated by different individual patterns of hybridization or introgression, with different management implications. Thus, the actual *pattern* of introgressive hybridization within a population has a more significant management implication than the %LCT value. For instance, a population with an overall "low" level of introgression could be a mixture of a few F1 individuals (each with 50% fractional ancestry) with many non-introgressed individuals; this situation points to a current and active presence of non-natives that can be managed through the evaluation (genetically) and removal of hybrid individuals from the population, as is currently being done in Independence Lake. In contrast, a population with an overall lower level of introgression (%LCT) could be composed of most or all individuals with lower levels of introgression (connoting a historical hybridization event that has now affected most individuals in that population, *i.e.*, a "hybrid swarm"). In this latter scenario, there may not be any practical or clear management options to improve the population's hybridization status.

Here, Hemstrom *et al.* (2022) drew from additional sequences from rainbow trout (Micheletti *et al.* 2018) and Yellowstone cutthroat trout (R. Kovach and M. Campbell, unpublished sequences) and performed admixture proportion estimation with ngsAdmix (Skotte *et al.* 2013), specifying three ancestral populations (K=3) assumed to represent the three parental species or subspecies (rainbow trout, and Lahontan and Yellowstone cutthroat trout). Values of %LCT representing the percent ancestry assigned to the LCT cluster were averaged across all individuals to get a population-level %LCT. The Peacock *et al.* studies (2004–2019) used diagnostic markers, where the number of loci with the LCT allele was averaged for each individual and %LCT was then averaged across individuals for the population-level %LCT estimate.

For the purposes of this review, potential LCT recovery populations with no introgressive hybridization (*i.e.*, generally considered uncompromised based on information available at the time of this review) scored a 4 (99–100% LCT), whereas populations with small levels of non-native genetic material scored a 3 (97–99% LCT), moderate levels a 2 (90–97% LCT), moderately high levels a 1 (75–90% LCT), and high levels a 0 (75% LCT or less). The Service has not produced clear guidance on how to best categorize hybridization of listed species yet, but these categories provide a conservative starting point and continuum for this review. Once again, due to the challenging nature of measuring, estimating, and categorizing introgressive hybridization, these data were interpreted with caution and in combination with other information to help tell each population's story. Also, the importance of individual hybridization patterns (versus the whole population %LCT value/rank) again emphasizes why results here should not be used as a full assessment of hybridization status, but rather to identify populations that are clearly influenced by non-native, hybridizing trout and attempt to classify the degree/timing of that hybridization if possible. Moreover, this analysis is not an attempt to determine if a population is no longer important to recovery, as there is no clear guidance in the literature or agreement among the scientific community regarding this topic currently (including among the LCT recovery partners). Lastly, it is also important to recognize that the amount of hybridization allowed within a resilient LCT recovery population has not been formally established; it is even possible, if not likely, that the %LCT value determined sufficient for LCT conservation will vary by management unit and/or population.

Demographic Resources Used to Evaluate Population Resiliency

***Population Abundance***

Population abundance was defined as the estimated total number of LCT (excluding young of year) within the extent of occupied habitat for each population. Young of year (YOY) were excluded from the estimates as they have not yet recruited to the population and were defined as fish smaller than 60 millimeters in surveys prior to August and smaller than 80 millimeters after August (Leasure *et al.* 2019, Neville *et al.* 2016). Abundance estimates were derived from the most recent electrofishing surveys conducted by field biologists for each population. The oldest survey used was from 2004. Surveys ranged from multiple-pass depletion surveys with 100 meter transects and block nets to single pass surveys of 30.5 meter transects and no block nets. Abundance estimates are likely to be biased low, resulting from inconsistent capture probability among individuals, as some fish are easier to catch (related to fish size, temperature, habitat complexity, etc.) than others (Rosenberger and Dunham 2005). In addition, sampling events that did not use block nets likely allowed fish to escape from electroshocking crews, which is also likely to lead to a lower abundance estimate.

For multiple-pass depletion surveys, abundance estimates followed a very similar methodology to the one defined in the Apache Trout Monitoring Plan (Dauwalter *et al.* 2017). Age 1+ LCT per transect were estimated using a Zippin removal estimator in the R package FSA. To extrapolate to population abundance, the mean fish number across all sampled transects was multiplied by the number of units within the entire occupied extent of the population. The estimated abundance of age 1+ LCT for population *i* is:

$$\widehat{N}_i = N_i \bar{y}_i = \frac{N_i \sum_{j=1}^{n_i} y_{i\,j}}{n_i}$$

Where $\widehat{N}_i$ is the estimated abundance of age 1+ LCT for population *i*, $N_i$ is the total number of sampling units available in the occupied extent for population *i*, $\bar{y}_i$ is the mean number of age 1+ LCT per transect across all transects *j* sampled in population *i*, $y_{i\,j}$ is the number of age 1+ LCT in transect *j* in population *i*, and $n_i$ is the number of transects sampled in population *i*. The variance of $\widehat{N}_i$ is:

$$\hat{V}\left(\widehat{N}_i\right) = \hat{V}(N_i \bar{y}_i) = N_i^2 \left(\frac{s_i^2}{n_i}\right)\left(\frac{N_i - n_i}{N_i}\right)$$

where $N_i$ and $n_i$ are as defined above, and $s_i^2$ is the variance in abundance in age 1+ LCT across all transects in population I, which is calculated as:

$$s_i^2 = \frac{\sum(\bar{y}_i - y_{i\,j})^2}{n_i - 1}$$

with all terms as defined above. $\left(\frac{N_i - n_i}{N_i}\right)$ is a finite population correction that shrinks the observed variance by the proportion of the habitat extent ($N_i$) sampled across all transects for population *i*. Variance is based on a simple random sample, if adjacent sample units (reaches) are uncorrelated and that $N_i$ is large. The variance $\hat{V}\left(\widehat{N}_i\right)$ is used to compute 80% confidence bounds on $\widehat{N}_i$; the upper 80% confidence limit is calculated as:

$$\widehat{N}_i + t_{a=0.2/2,n_{i-1}} \sqrt{\hat{V}(N_i \bar{y}_i)}$$

And the lower 80% confidence limit is calculated as:

$$\widehat{N}_i - t_{a=0.2/2,n_{i-1}} \sqrt{\hat{V}(N_i \bar{y}_i)}$$

where $\hat{V}(N_i \bar{y}_i)$ and $n_i$ are defined above, $t_{a=0.2/2,n_{i-1}}$ is the t-value from a t-distribution table at α=0.2/2=0.1 and $n_i - 1$ degrees of freedom[2]; α is divided by 2 for each side of the confidence interval to match the total α of 0.2 for an 80% confidence interval.

For single pass sampling events, the catch on the pass was adjusted by an appropriate measure of capture probability (p) for that population or a similar stream using estimates from the Population Viability Analysis shiny app, Adjusted Catch = Catch [age 1+] / p (Leasure *et al.* 2019, Neville *et al.* 2019). Following this adjustment, abundance was calculated like the multiple-pass depletion sampling events using the above calculations.

The exceptions to these methods include Murphy Creek (Walker LMU), and Whitehorse Creek Complex and Willow Creek (Willow-Whitehorse LMU). Murphy Creek employed an adaptive sampling protocol and abundance estimation approach as described in Schaeffer *et al.* (2012). Both Whitehorse Creek Complex and Willow Creek abundance estimates were provided *via* digital comment from Oregon Department of Fish and Wildlife, which used the SPSurvey package in R (ODFW 2022). The LCT occupied habitat map layer was also updated as part of this review to better estimate population abundances (see maps included in the Review Analysis section below and information presented it the review text above). In short, the map set used for this review was updated from the 2019 UGOs effort and included mostly refinement of the upper and lower populations distribution limits. Regardless of the methods used to estimate population abundance, abundances above 2,500 received a score of 4, between 1,001 and 2,500 a score of 3, between 501 and 1,000 a score of 2, between 101 and 500 a score of 1, and below 100 or fewer a score of 0. Although the scientific community continues to debate how many individuals are enough in a population to maintain said population, these categories are generally well-accepted within the literature (*e.g.*, Franklin 1980, Nelson and Soulé 1987, Allendorf *et al.* 1997, Hilderbrand and Kershner 2000, Reed *et al.* 2003, in addition to references included in the *Effective Population Size* section above).

### ***Number of Age Classes***

Fish age is conventionally determined through examination of the otolith, vertebrae, or other hard bony body parts (Helfman *et al.* 2009). However, this form of analysis is generally a lethal and time-consuming process, and thus this type of data is not available for the majority of LCT populations. An alternative method is to use length-frequency distributions to indirectly estimate fish age, which employs an assumed correlation of length and age (Macdonald and Pitcher 1979). It is important to note that sufficient variation in size at any age exists in most species, including LCT, which makes it difficult to estimate exact age with high precision (Helfman *et al.* 2009). In addition, many existing potential LCT recovery populations are isolated within small headwater streams habitat fragments that are not likely to support large-sized fish; therefore, a two-year-old fish in this type of habitat is generally smaller than a two-year-old fish in a larger, more productive system. Lastly, a large sample size provides the best estimation of the age structure within a population. Here, 34 of the 71 analyzed LCT populations had a sample size smaller than 60 individuals, which results in a less confident estimation of age/length relationships; however, this may still provide an indication of the number of age classes within the population, and so once again, these data were interpreted with caution and as part of each population's story. The most recent data for each population were used, with collection years ranging from 2007 to 2021; once again, it was recognized that there is a large amount of uncertainty when using older data, and so caution was used while interpreting data and making decisions regarding scores related to this metric and subsequent population categorization.

Length data for each population was converted to standard length using a regression relationship developed from historical data with multiple length types (total, fork, and standard lengths) in the sampling event. The data were binned into 5 millimeters increments, and the frequencies (number of individuals) in each bin were grouped into a histogram. The objective was to fit a theoretical distribution by finding the mixing proportions, means, and standard deviations that make the difference between the theoretical distribution and observed histogram as small as possible (Macdonald and Pitcher 1979); this process often required multiple iterations of theoretical distributions to determine the best fit. The analysis was conducted with the mixdist CRAN package in R Studio (Macdonald and Du 2018) (Figure 1B). The formula used is a mixed probability density function $g$, being a weighted sum of $k$ component densities, where $k$ is assumed to be known:

$$g(x|\pi, \mu, \sigma) = \pi_1 f(x|\mu_1, \sigma_1) + \cdots + \pi_k f(x|\mu_k, \sigma_k)$$

For scoring purposes, YOY were excluded from the count of age classes, as those individuals have not yet recruited to the population and have a low capture probability that varies with time of year (Rosenberger and Dunham, 2005). Because the Adult Lifespan (AL; see Effective Population Size section above) of LCT in most of the potential recovery populations was calculated as 5, this became the maximum number of age classes expected within most populations, receiving the highest score of 4; 4 age classes then received a score of 3, with 3 age classes scoring a 2, 2 age classes scoring a 1, and 1 age class scoring a 0.

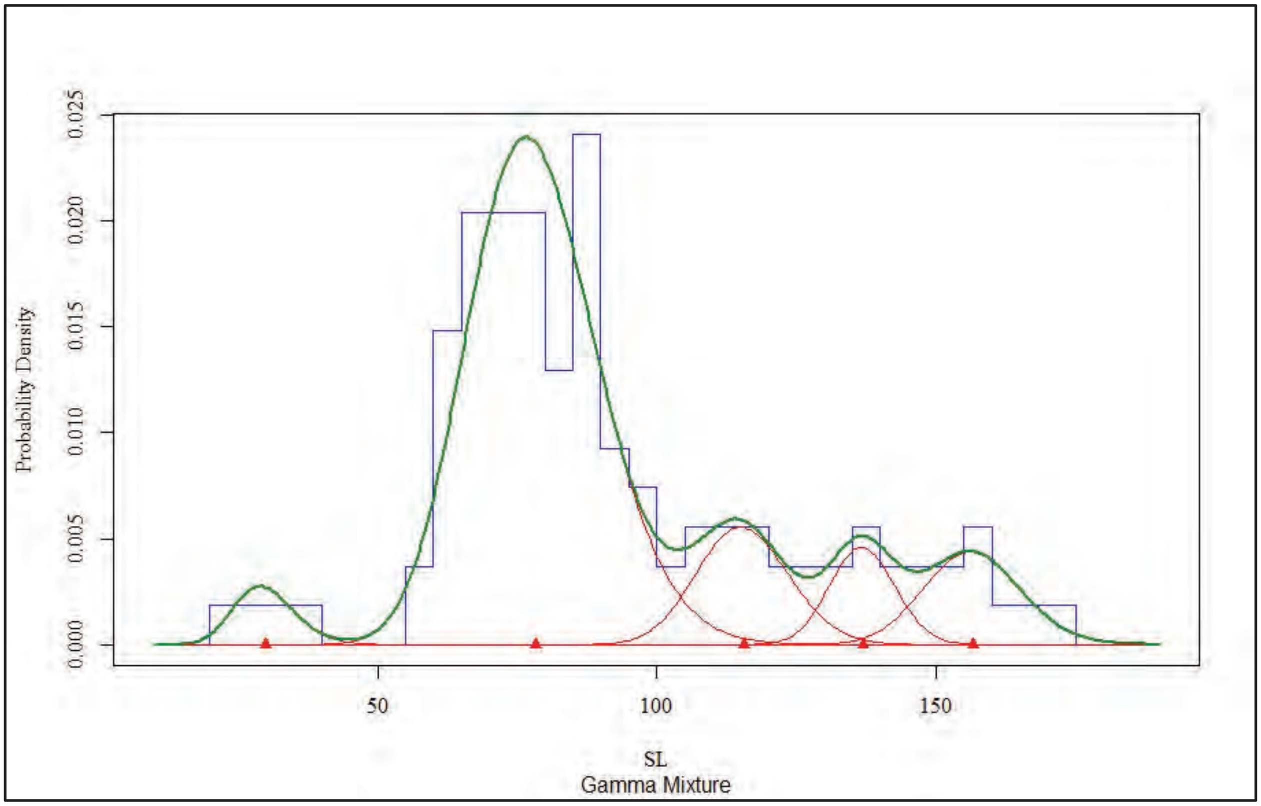


**Figure 1B.** A gamma distribution of Foreman Creek, 2016 data, with five age classes.

## Expert Opinion

As part of this Status Review process, expert opinion was solicited for several purposes. The first was to assess the data-derived scores and determine if expert opinion was in line with them as this was the first attempt to bring all relevant LCT population resiliency data and information together to date. In addition, expert opinion data were used in this review analysis for populations that did not have adequate or recent data or were used to determine how to rank/interpret data that was older and/or had very low sample sizes (all instances are explained within the population-level descriptions in Appendix C: Technical Results). Each expert was asked to score, using Table 1 (in review text above), each of the demographic and genetic health metrics that were used to assess LCT population resiliency in this review prior to seeing Table 2 (also in review text above). Each expert was required to subsequently provide comments/reasoning related to each population they manage/scored as well. These data were collated and averaged (where two or more experts scored the same population) to produce a table like Table 2. To confirm expert opinion scores and subsequent ranks, and to review the results provided in Table 2, a half-day workshop occurred on May 11, 2022, with all experts that provided data used in this review; all discrepancies were reviewed and resolved at that time or in subsequent correspondences.

Only technical and field staff with multiple years of experience sampling LCT populations analyzed in this review were asked to submit expert opinion; those experts included: David Banks (ODFW District Fish Biologist), Jason Barnes (Trout Unlimited LCT Coordinator), Cody Byrne (NDOW Eastern Region Fisheries Supervisor), Travis Hawks (NDOW Western Region Fisheries Supervisor), Jacob Stoller (NDOW Eastern Region Fisheries Biologist), Mike Starr (NDOW Eastern Region Fisheries Biologist), Kris Urquhart (NDOW Western Region Fisheries Biologist), Nick Buckmaster (CDFW Heritage and Wild Trout Biologist), Leslie Alber (CDFW District Region 2 Sierra Fisheries Supervisor), and James Simmons (SLPT Natural Resources Director). In addition, Dr. Mary Peacock (UN Reno Professor/Researcher) and Dr. Helen Neville (Trout Unlimited Senior Scientist) were asked to participate in the process given their intimate familiarity with most of the existing potential LCT recovery populations. This group also reviewed drafts of the results write-ups below and provided input. Service employees Chad Mellison, Andy Starostka, Lisa Heki, Tim Loux, and Melissa Conte also contributed to this exercise and/or the results write-ups presented in the next appendix. Expert opinion was in some cases guided by previous knowledge with the demographic or genetic health data described above, and in others, the history of a population, its current or actual status (potentially not reflected in the most recent data), recent management activities, and other personal experiences.

# APPENDIX C: TECHNICAL RESULTS

## Carson Management Unit (CMU)

The updated objectives for LCT in the Carson Management Unit (CMU) are:

1. Remove threats (*i.e.*, competition, predation, hybridization) associated with non-native trout species to allow for the formation and/or maintenance of CMU LCT populations identified in CMU objectives 3–4; and
2. Ensure all habitats required to meet CMU objectives 3–4 function ecologically. In some cases, this may require restoration and/or management changes; and
3. Establish meta-population dynamics within at least 1 recovery population; and
4. Establish at least 2 additional recovery populations in the Upper Carson hydrologic unit, spatially separated from each other and the meta-population required by CMU objective 3.

There are four potential LCT recovery populations in the CMU currently. All the populations are in relatively small headwater stream fragments in the East Fork of the Carson River (Figure 1C). These populations ranked on the low end of the potentially resilient category (2.0–2.2; Table 2 within review text above), with low abundances and effective population sizes, but high age-class and hybridization status scores. However, these populations are unlikely to be resilient without increasing the amount of habitat available to each of them; the only realistic management option is to reconnect these populations into one, large and interconnected population that would likely display metapopulation dynamics instead of several isolated ones. This is the only realistic way to meet the 3rd CMU updated objective as well.

Over the last several years, interagency partners have been evaluating potential barrier locations downstream of the isolated LCT populations that would allow them to be reconnected into one resilient LCT recovery population. This barrier would need to be a relatively large, permanent fish barrier structure to halt upstream movement of non-native trout after construction. Non-native fish above the barrier would need to be removed after its construction to allow a resilient LCT recovery population to form (and helping to complete the 1st CMU objective). Interagency partners have been working together to improve relationships with each other and local stakeholders to this end; however, it is unclear if this project is possible in the near future at this time. As of today, although stream habitats in the Carson River watershed generally function ecologically and are in good condition, none of the updated conservation objectives for LCT have been accomplished.


**Figure 1C.** LCT occupied habitat within the Carson Management Unit.

## Humboldt Management Unit (HMU)

The updated conservation objectives for LCT in the Humboldt Management Unit (HMU; Figure 2C) are divided into eight hydrologic units due to the size of this LCT Management Unit (LMU); they collectively include:

HMU Wide:

1. Remove threats (*i.e.,* competition, predation, hybridization) associated with non-native trout species to allow for the formation and/or maintenance of HMU LCT populations identified in HMU objectives 3–13; and
2. Ensure all habitats required to meet HMU objectives 3–13 function ecologically. In some cases, this may require restoration and/or management changes; and
3. Maintain existing, isolated populations that cannot individually meet the recovery population benchmarks provided in 2019 UGOs. Actively manage those populations based on guidance provided in the pending LCT Genetics Management Plan (GMP).

Three of the eight, 8-digit USGS hydrologic units were not included in the 2019 UGOs as they did not contain sufficient suitable, cold-water fish habitat at that time. One of those hydrologic units, Pine, contains two potential LCT recovery populations in Birch Creek and in Pete Hanson Creek (Figure 3C). The LCT population in Birch Creek ranked as unlikely to be resilient with dwindling abundances and low genetic health metrics (see Table 2 in review text above), due to reduced water availability through time possibly as a result of climate change. The Pete Hanson Creek LCT population ranked as potentially resilient with relatively high abundance and age-class metrics, but low genetic health metrics (Table 2); this population is in approximately 4.7 miles of relatively high-quality habitat without the presence of non-native trout, so this ranking fits. It is unclear how to improve the genetic health of these populations; however, these fish are most closely related to populations from the Reese Management Unit. These populations are partially meeting the 3rd updated objective for the HMU and are to be maintained until the LCT GMP is completed and these populations are specifically addressed in the formal Recovery Plan revision process. No additional LCT populations exist in the HMU that are not included within the five hydrologic unit descriptions below.

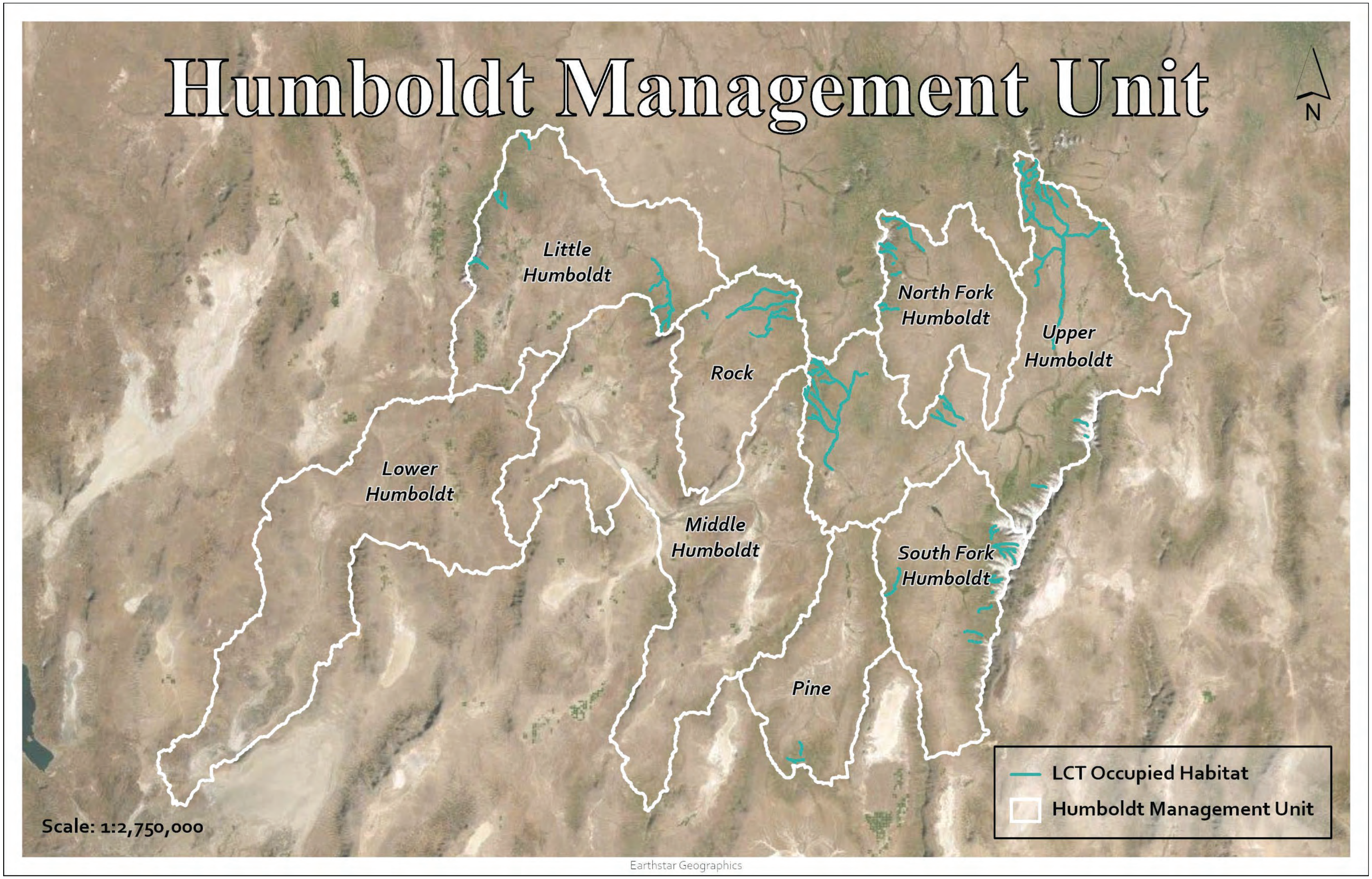


**Figure 2C.** LCT occupied habitat within the Humboldt Management Unit.

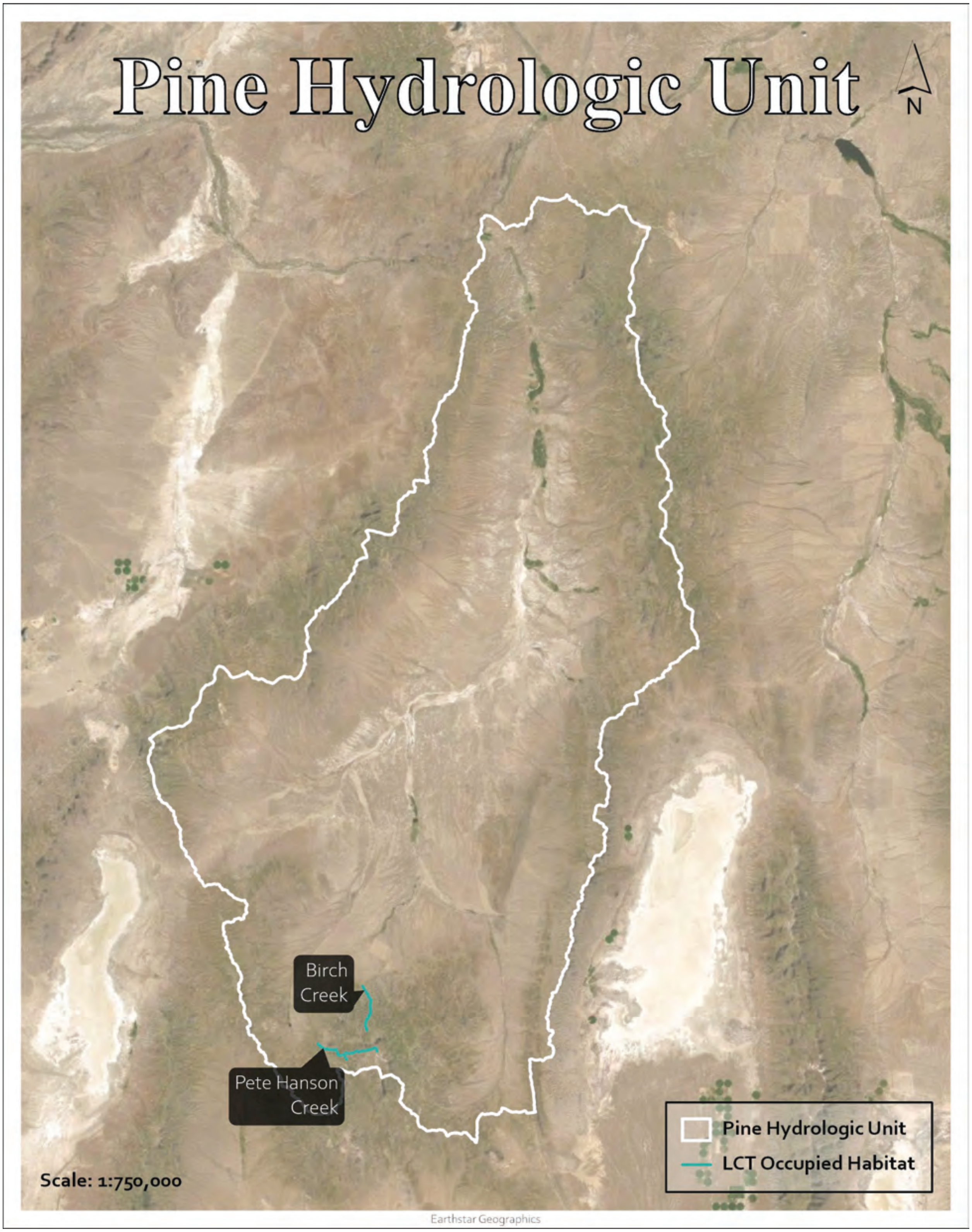


**Figure 3C**. LCT occupied habitat within the Pine hydrologic unit.

Little Humboldt hydrologic unit:

4. Maintain meta-population dynamics in 1, and establish meta-population dynamics in at least 1 additional, recovery population; and
5. Establish at least 1 additional recovery population that is spatially separated from the meta-populations required by HMU objective 4.

There are four potential LCT recovery populations in the Little Humboldt hydrologic unit currently (Figure 4C), with results from unlikely to be resilient to potentially resilient (see Table 2 in review text above). The South Fork of the Little Humboldt River contains an interconnected LCT population that is potentially resilient today as it is limited by several factors. Moderately low genetic metrics drove the score for this population down below the mark considered to be resilient. In addition, past genetic assessments indicate that rainbow trout hybridization may be occurring within portions of the population (Peacock 2019); however, it is unclear how widespread the threat is or how to best manage the genetic health of this population right now. This system has likely contracted through time because of reduced water availability likely due to climate change, corroborated by 2022 field sampling (J. Barnes, pers comm. 2022). This population may have the potential to become resilient in the future, but the magnitude and duration of the intervention needed to get there is unclear today. Interagency partners prioritized the genetic sampling of this population this year to inform future management actions. None of the other populations in this hydrologic unit are resilient at this time either and thus none of the updated conservation objectives have been fulfilled.

The remaining potential LCT recovery populations in this hydrologic unit flow east off the Santa Rosa Range and include the Abel, Indian/South Fork (SF) Indian, and Long Canyon Creek populations (Figure 4C). None of these populations are currently resilient (Table 2), with Abel and Indian/SF Indian Creeks having the potential to be resilient (at least more resilient than they are today) in the future. Abel Creek currently contains both LCT and non-native brook trout. Stonehouse Creek and North Fork Abel Creek, both connected to Abel Creek, also have brook trout, but do not contain LCT. Efforts are currently underway to remove brook trout from these interconnected creeks using "Trojan Male" or YY-Male brook trout fish to shift the sex ratio and reduce the long-term viability of the brook trout population (Schill *et al.* 2016, Kennedy *et al.* 2018, McCormick *et al.* 2021, NDOW 2021a); with additional genetic management, this should allow this population to move into a state of resiliency, albeit 10–15 years from now. The LCT population within Indian/SF Indian Creek also ranked as potentially resilient due to low genetic health metrics, although the population contains genetically pure LCT (Table 2); it is currently unclear how to improve the resiliency of this population. However, the pending LCT GMP will provide guidance about how to best manage these types of populations moving forward. Lastly, the LCT population within Long Canyon Creek is unlikely to be resilient due to low to moderately low genetic health metrics and relatively low abundance (Table 2). Although hybridization with rainbow trout has been a problem with this population in the past, management efforts and reductions in water quantity have aided in the removal of most non-native trout; however, those reductions in water quantity, in combination with reduced habitat quality throughout this basin, have reduced the resiliency of this population. Current efforts are only focused on ensuring non-native trout are removed when encountered within this population;

there are no plans at this time to address the threat of habitat loss or degradation that is acting to reduce population resiliency and thus no reason to believe the situation will change soon.

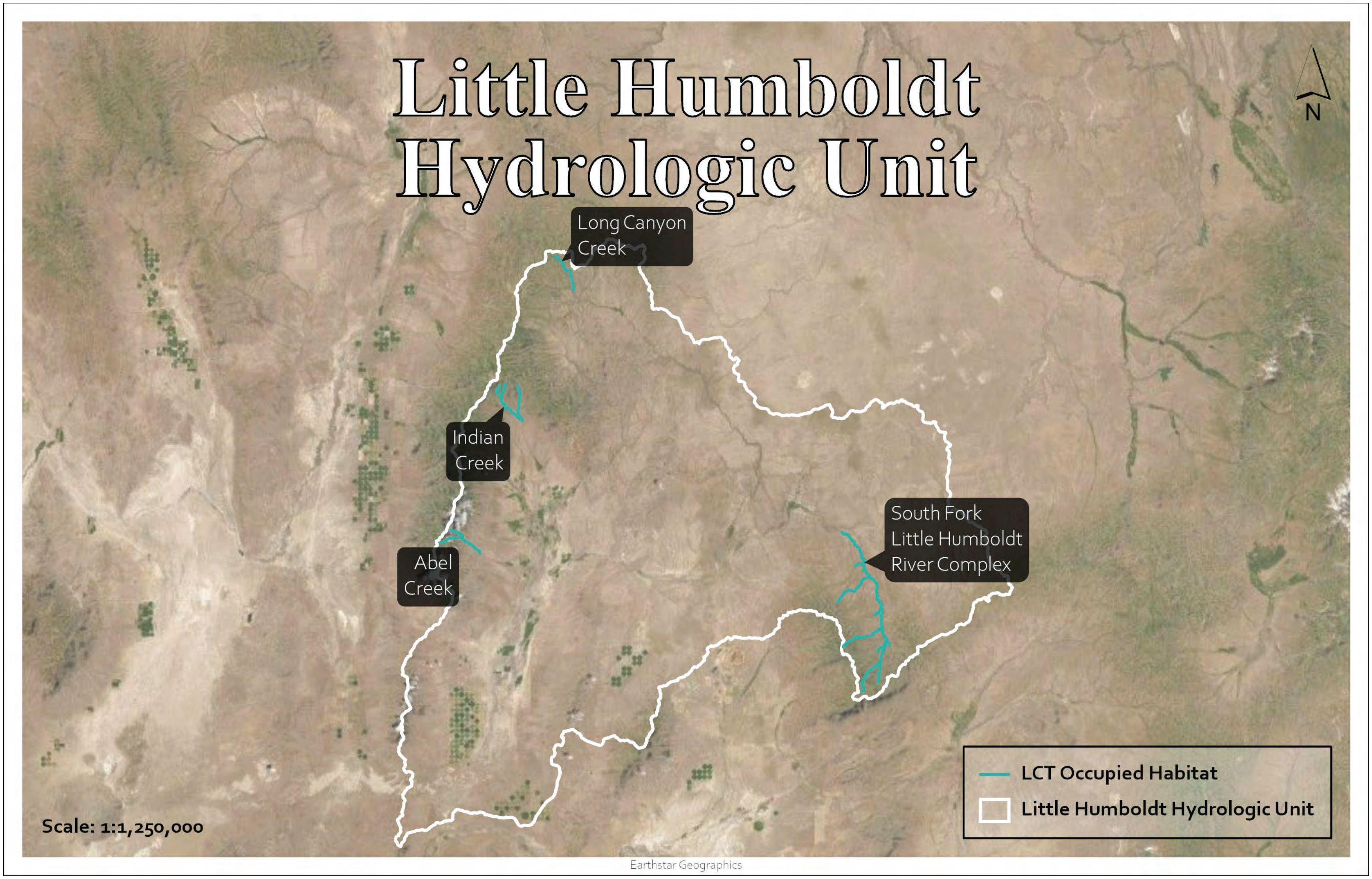


**Figure 4C.** LCT occupied habitat within the Little Humboldt hydrologic unit.

North Fork Humboldt hydrologic unit:

6. Establish meta-population dynamics in at least 1 recovery population; and
7. Maintain (or establish if necessary) at least 1 additional recovery population that is spatially separated from the meta-population required by HMU objective 6.

The North Fork Humboldt hydrological unit contains six potential LCT recovery populations (Figure 5C); however, two of these are at risk of extirpation (California Creek and Winters Creek) because of very low abundances likely due to a lack of consistent water availability. The remaining four populations, North Fork Humboldt River Complex, and Foreman, Pratt, and Gance Creeks (which also includes the connected Road Canyon and Warm Creeks), were all categorized as potentially resilient for a variety of reasons.

The North Fork of the Humboldt River contains pure LCT above a barrier that protects the upper portion of the system from non-native trout. The barrier was installed in response to mining activities in the area, which has resulted in acute impacts to this population from dewatering. Over the last six years, several chemical treatments have occurred to remove non-native trout from below that barrier. Additional work has also been done to interconnect the upper portion to the mainstem and other tributary streams, including portions of Dell, McAfee, and Walker Creeks (although connectivity issues will still need to be addressed to allow for unrestricted fish movement); over the next several years, once these systems are confirmed to be cleared of non-natives, LCT will be moved into the newly cleared habitat (and will naturally repatriate from upstream as well). This should shift this population into a resilient state and meet the 6th updated objective in the HMU within the next 5 to 10 years.

The LCT populations in Foreman, Pratt, and Gance Creeks all flow east from the Independence Range and were categorized as potentially resilient (see Table 2 in review text above). Foreman Creek fell just short of being categorized as likely resilient due to relatively lower abundance and effective population size metrics. Pratt Creek lacked recent data because it was only recently reestablished; expert opinion was used and was based on the history of fish translocations into this population. Only 354 LCT have been moved into this population from neighboring ones to date, so the categorization fits. Lastly, Gance Creek also fell just short of being classified as likely resilient due to lower number of age-classes and low effective population size. It is possible that recent drought and wildfire affected the age-class structure and effective population size of these populations recently, depressing those metrics prior to this review.

Nevertheless, it appears that all these populations, including the North Fork of the Humboldt River, should benefit from some genetic management; guidance from the LCT GMP will address how to initiate that process. Based on what is known today, it appears that all the populations in this hydrologic unit could be moved into a state of resiliency with improved population management. However, changing habitat conditions and deleterious land use practices in and near these populations may outweigh the good of improved population management. The presence of non-native trout will continue to be closely monitored in this basin until that threat is effectively removed. Currently, there are no plans to address the threats related to habitat loss/degradation in this hydrologic unit. None of the updated objectives have been met for the North Fork Humboldt hydrologic unit.

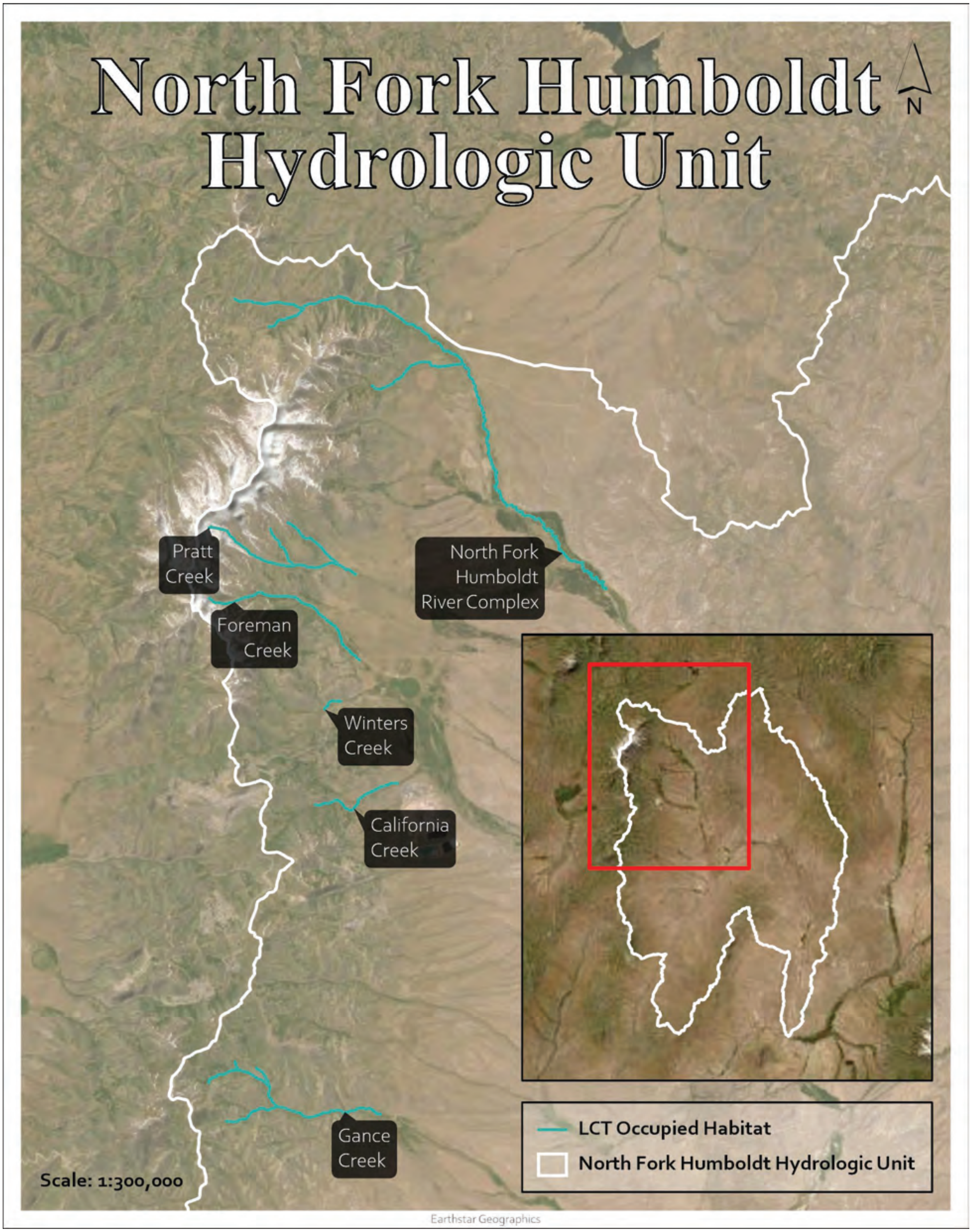


**Figure 5C.** LCT occupied habitat within the North Fork Humboldt hydrologic unit.

Rock hydrologic unit:

8. Maintain meta-population dynamics in at least 1 recovery population; and
9. Maintain (or establish if necessary) at least 1 additional recovery population that is spatially separated from the meta-population required by HMU objective 8.

The Rock hydrologic unit contains three potential LCT recovery populations currently (Figure 6C), all of which ranked out as potentially resilient (see Table 2 in review text above). All these populations have low effective population sizes and moderately low genetic diversity metrics; improvement in these metrics, *via* assisted migration, should improve resiliency with relatively low effort pending guidance from the LCT GMP. However, a fish stocking accident introduced non-native rainbow trout into Willow Creek Reservoir in late 2019; when discovered, recovery partners chemically treated and drained the reservoir system by mid-2020 to reduce the likelihood that those fish could enter the creek system and hybridize with LCT. Unfortunately, preliminary environmental DNA (eDNA) analysis detected non-native rainbow trout genetics in the Willow Creek system in 2021; however, it is unclear if the results are due to the recent accident or from legacy stocking events that are only now being detected due to more rigorous sampling efforts. Thus, it is a priority to fully sample the Rock Creek and Willow Creek Complex and Reservoir in 2022 to better understand how widespread the threat of hybridization with non-native rainbow trout is prior to any genetic management actions.

Stream habitat restoration and improved grazing management activities have improved riparian habitat conditions throughout this hydrologic unit over the last two decades (Booth *et al.* 2012). Interagency partners have received funding for and committed to continuing habitat restoration in portions of these streams, including improving infrastructure to better manage grazing activities. However, recent drought conditions, in combination with continued grazing, have negatively impacted many of the tributary streams and their inputs (S. Vogt pers. observation 2022). Once genetic sampling is complete, genetic management actions can occur that will likely improve the resiliency of these populations. However, because of the unclear nature of the threats in this hydrologic unit at this time, it is not possible to determine when these populations can reach a state of resiliency. Currently, none of the hydrological unit’s updated objectives have been met.

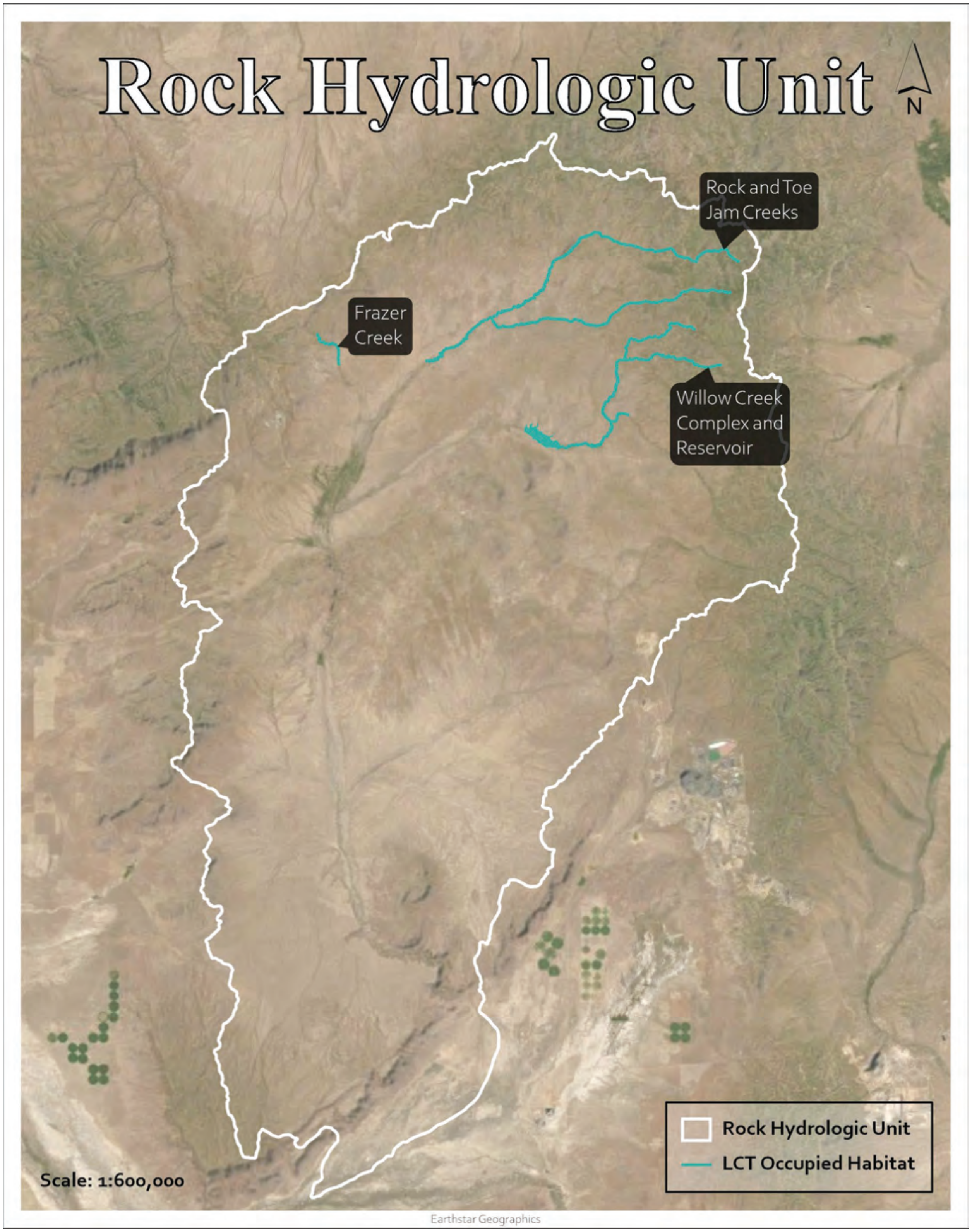


**Figure 6C.** LCT occupied habitat within the Rock hydrologic unit.

South Fork Humboldt hydrologic unit:

10. Establish meta-population dynamics in at least 1 recovery population; and
11. Maintain (or establish if necessary) at least 2 additional recovery populations that are spatially separated from each other, and the meta-population required by HMU objective 10.

The South Fork Humboldt hydrologic unit currently contains nine potential LCT recovery populations (Figure 7C), with results varying from at risk of extirpation to likely resilient (see Table 2 in review text above). Abundance and genetic metrics from this unit were extremely variable, with limited robust sampling occurring in the past. However, three of the nine populations (Green Mountain, McCutcheon, and Welch Creeks) are at risk of extirpation currently. Welch and Green Mountain Creeks have limited water availability at this time, so no real management options exist to secure these populations (Starr 2016c, Starr 2018). If non-native trout were removed from McCutcheon Creek and it was subsequently reintroduced with LCT, then this stream system could likely support a resilient population. Private landowner cooperation, barrier construction, and non-native fish removal would be required; this would likely take more than ten years to accomplish given current workload and existing relationships.

Of the remaining six populations, Brown and Lee Creeks, as well as the Smith and Long Canyon Complexes, were ranked as potentially resilient populations. Dixie Creek was ranked as unlikely to be resilient, with declining population trends through time, likely due to changes in water quantity and quality despite a legacy of habitat restoration and improved grazing management (Evans and IWJV 2021). Thus, without additional management options to improve the resiliency of this population, it is not likely that its status can improve. Lastly, Pearl Creek ranked out as one of the five likely resilient LCT recovery populations range wide; although, like many other populations discussed in this review, its resiliency could likely be improved by genetics management actions to bolster genetic health metrics. Pearl Creek continues to partially (maintenance of 1 of the 2 recommended redundant, resilient populations) meet the 11$^{th}$ updated objective for the HMU. However, none of the updated conservation objectives for this unit are fully achieved at this time.

The potentially resilient populations were ranked as such for variable reasons. Brown Creek is a newly reestablished LCT population (2020, 2021, with plans to augment in 2022), without sufficient data to fully understand its present status. Lee Creek did not meet the definition of likely resilient because of low effective population size, abundance, and age-class metrics (Table 2); fish within this population are occupying all the available habitat, which is approximately one mile, so there are no real management options here to increase its resiliency in the future and thus this population is unlikely to be resilient. Both the Smith and Long Canyon Complexes contain LCT and other non-native trout at this time; both systems have the potential to meet the updated conservation objectives and have been discussed by interagency partners in the past. Recently, interagency partners began collaboratively working with the private landowners and stakeholders in the Long Canyon Complex area to determine how to move that project forward. To reestablish a resilient LCT population in the Long Canyon Complex, a barrier to protect the new population would need to be constructed, non-native fish removed, and LCT allowed to repatriate (and likely be genetically managed *via* guidance within the pending LCT GMP); this will take at least 10 or more years to complete given the scale of the project.

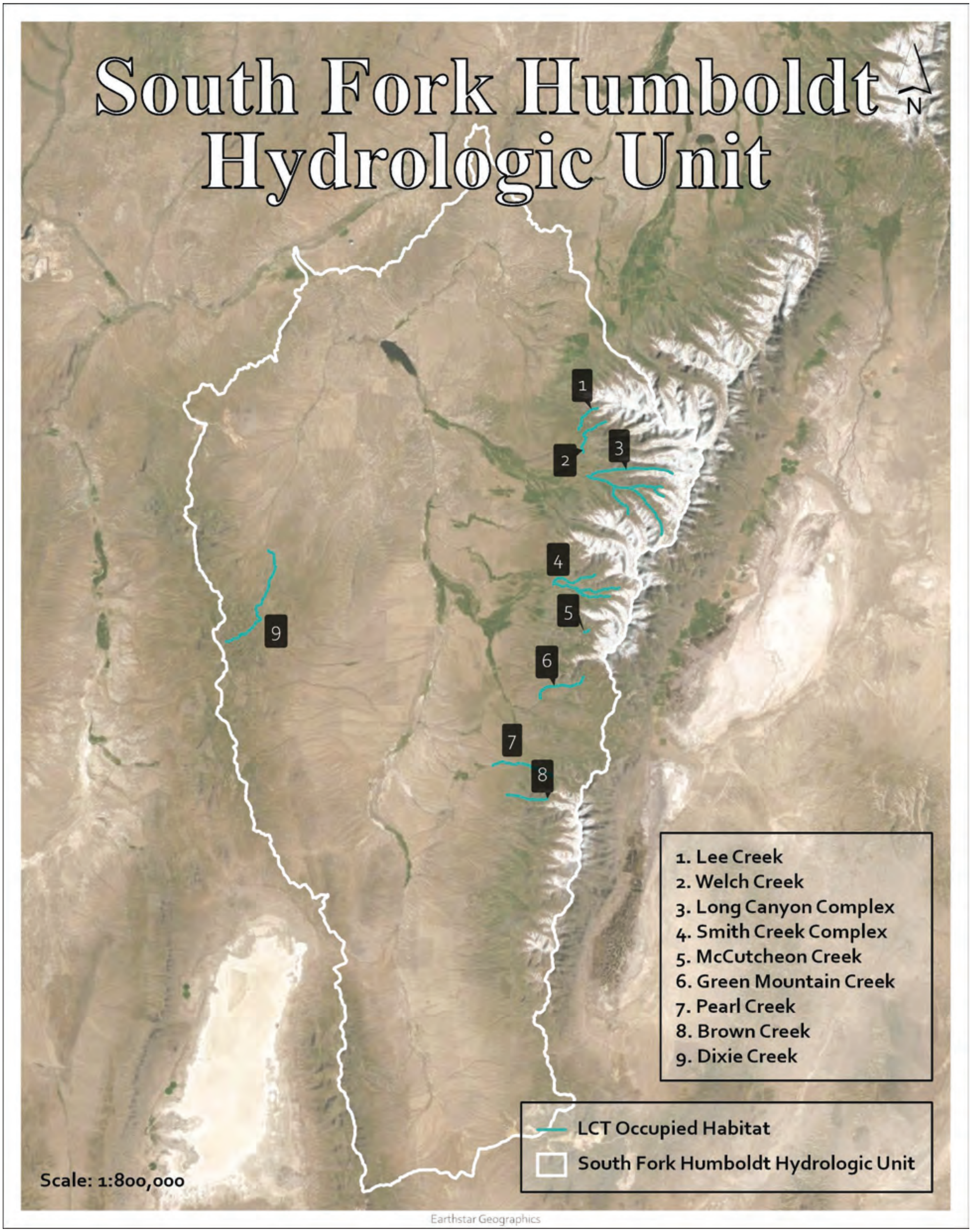


**Figure 7C.** LCT occupied habitat within the South Fork Humboldt hydrologic unit.

Upper Humboldt hydrologic unit:

12. Maintain meta-population dynamics in 2, and establish meta-population dynamics in at least 1 additional, recovery population(s); and
13. Maintain (or establish if necessary) at least 3 additional recovery populations that are spatially separated from each other, and the meta-populations required by HMU objective 12.

The Upper Humboldt hydrologic unit is the most complex unit within the HMU and contains the highest number of populations in the HMU (Figure 8C), including two (Marys River and Maggie Creek) of the five likely resilient LCT recovery populations (Table 2 within review text above). Marys River was ranked as likely resilient, with high marks in all but effective population size; however, preliminary eDNA analyses provided evidence of non-native rainbow trout throughout the mainstem of this system (NDOW 2019). In addition, habitat conditions along several tributaries to Marys River, especially in the eastern sub-basin, are failing to serve an ecological function (*e.g.*, Hanks Creek) (Stoller 2016, Stoller 2020, Stoller 2021). Therefore, the LCT population within Marys River is likely less resilient today than the available data indicate; interagency partners have prioritized the systematic genetic sampling of this population between 2022–2024 to determine how to reduce the threat of non-native trout over time. At this time, it is unclear how long it will take to determine the source of non-native trout (also ensuring that it is removed as a pathway for reintroduction) and to employ a strategy to remove them.

Three remaining populations would otherwise be connected, on years with normal to above average precipitation, to Marys River (T/Draw, Wildcat, and Currant Creeks) if it were not for poor habitat conditions and/or water diversions (Figure 8C). The LCT population in T/Draw Creeks was categorized as potentially resilient, with low effective population size and age-class metrics (Table 2); the abundance and age-class data used for this analysis were dated (2004 and 2010, respectively) and contained low sample sizes (*e.g.*, n=10 from age-class estimation), so these ranks are possibly inflated positively and negatively biased, respectively. Wildcat and Currant Creek also contain small LCT populations that were categorized as unlikely to be resilient, with low to moderately low marks in all but the hybridization status category (Table 2). It is unlikely these three isolated populations will become resilient in the future due to flow permanence issues that greatly reduce water availability in the summer months. Long-term recovery planning to increase resiliency includes reconnecting these systems to facilitate natural gene flow *via* Marys River; however, a better understanding of the threat that non-native trout play in this complex is essential prior to reconnecting systems, so it is unclear when this may occur.

On the other hand, the resilient LCT population within the Maggie Creek Complex appears to be secure at this time, with little indication of hybridization or introgression with non-native rainbow trout historically, a lack of other non-native trout, a legacy of improving habitat conditions and connectivity of this system over time, and relatively high genetic diversity marks when compared to other LCT populations throughout the range (Table 2, Neville *et al.* 2016). There is some concern related to the long-term impacts of mining operations in the area, which will be addressed in the pending future scenarios analyses. Habitat restoration and improved grazing management actions continue to improve riparian habitats throughout this system (BLM

1993, Kozlowski *et al.* 2016). Future work here, and in the Marys River, to improve genetic health metrics, will likely improve resiliency (guidance pending in the LCT GMP) but is not a priority at this time. Maintenance of these two large, interconnected recovery populations that display meta-population dynamics partially fulfills the 12$^{th}$ updated objective (2 of the 3 meta-populations recommended) for the HMU pending the hybridization information to confirm their status.

Of the other five populations, three were ranked as potentially resilient (Fourth Boulder, Jackstone, and North Fork Cold Creeks) and two as unlikely to be resilient (Second Boulder and Sherman Creeks). Fourth Boulder and Second Boulder Creeks flow west from the East Humboldt Range and are part of a larger, interconnected stream system (Figure 8C); North Fork Cold Creek is also a tributary to a larger, interconnected Cold Creek Complex that flows west off the Ruby Mountains. Both systems have the potential to become resilient recovery populations, however, functioning relationships with private landowners in the area need to be developed before these large-scale projects can be developed. These types of projects require significant planning resources after relationships are formed and would take at least a decade or two to complete. Currently, there are no plans in place to assess these populations to provide a baseline or to move these projects forward. The remaining two populations contain LCT that do not show signs of hybridization but are unlikely to be resilient due to low to moderately low genetic health and age-class metrics (Table 2). Jackstone and Sherman Creeks contain neighboring LCT populations that could potentially benefit from being managed as a “population unit” (see description below in the Quinn Management Unit); guidance for what this might look like will be provided in the LCT GMP. In addition, how these populations fit into the recovery equation will need to be better described in the formal Recovery Plan revision process.

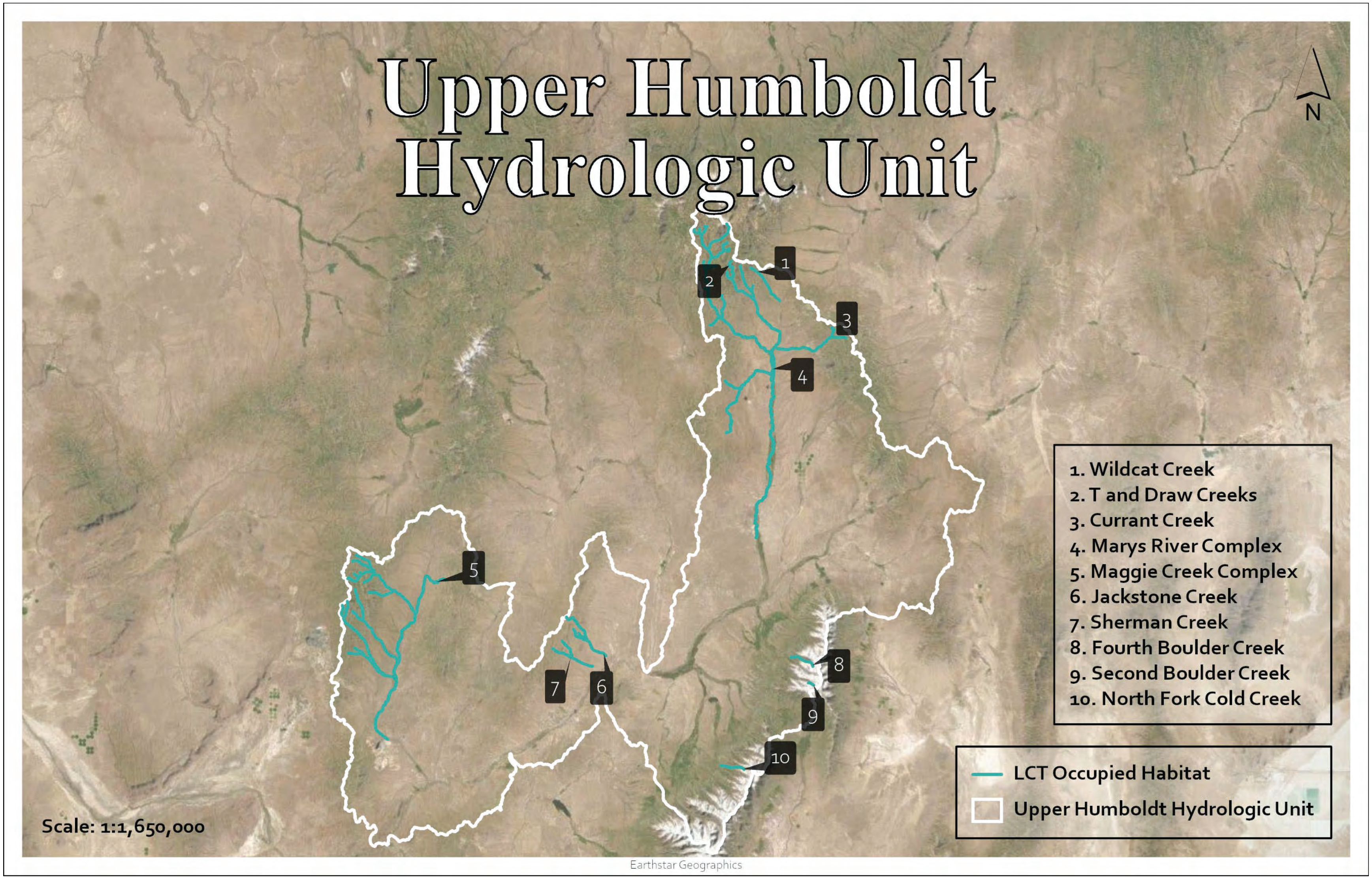


**Figure 8C.** LCT occupied habitat within the Upper Humboldt hydrologic unit.

## Quinn Management Unit (QMU)

The updated objectives for LCT in the Quinn Management Unit (QMU) are as follows:

1. Remove threats (*i.e.*, competition, predation, hybridization) associated with non-native trout species to allow for the formation and/or maintenance of QMU LCT populations identified in QMU objectives 3–5; and
2. Ensure all habitats required to meet QMU objectives 3–5 function ecologically. In some cases, this may require restoration and/or management changes; and
3. Establish meta-population dynamics in at least 1 recovery population; and
4. Establish at least 2 additional recovery populations that are spatially separated from each other and the meta-population required by QMU objective 3; and
5. Maintain existing (or establish new if necessary), isolated populations that cannot individually meet the recovery population benchmarks provided in the 2019 UGOs. Actively manage those populations together based on guidance provided in the pending LCT Genetics Management Plan to result in at least 2 additional recovery populations.

There are currently 10 potential LCT recovery populations in the QMU (Figure 9C), with variable results from at risk of extirpation to potentially resilient (see Table 2 in review text above). Overall, populations within this LMU ranked low in effective population size and genetic diversity; this is likely because these populations are generally in small headwater streams, with lower abundances. Several of the QMU populations are hybridized with Yellowstone cutthroat trout (YCT) to variable degrees (*e.g.*, Threemile and Falls Canyon Creeks) or non-native rainbow trout (Jackson Creek). There is not a clear path forward for how to manage these populations' genetics currently, but this will be addressed in the pending LCT GMP.

Of the 12 potential LCT recovery populations previously described in the 2019 UGOs, 2 are now extirpated (Pole and Riser Creeks), 1 is at risk of extirpation (Eightmile Creek), 7 are unlikely to be resilient, and 2 (Battle and Colman Creeks) are potentially resilient (Table 2). Pole and Riser Creeks have had multiple electrofishing and eDNA surveys conducted over the last several years to confirm LCT are no longer present (NDOW 2020a, NDOW 2020b). The LCT population in Eightmile Creek is at risk of extirpation, with abundances in the teens to single digits during the summer; only a small portion of the stream stays wetted during drought years (NDOW 2020a). The LCT populations within Andorno, Falls Canyon, and Threemile Creeks flow west from the Santa Rosa Range (Figure 9C) and are unlikely to be resilient as isolated populations; it is likely that none of these populations exist in large enough habitat fragments to contain enough individuals to maintain genetic health metrics through time. However, as presented in the 2019 UGOs and pending guidance from the LCT GMP, these populations could potentially be managed as a "population unit" *via* regular assisted migration. This is logical given their proximity to each other and that they would otherwise be connected if it were it not for agricultural water diversions and ranching/farming water withdrawals.

The LCT population within Sage, Line, and Corral Canyon Creeks was categorized as potentially resilient (score of 2.0); however, recent preliminary data indicates non-native rainbow trout hybridization may be occurring within portions of this population and a changing climate along with degraded habitat conditions have been reducing water quantity and quality through time (ODFW 2022). Currently, it is unknown whether this population could be managed as a resilient one on its own given its size and isolated nature. However, Sage, Line, and Corral Canyon Creeks are tributaries to the larger McDermitt Creek stream system. A previous attempt (initial treatment of Cottonwood Creek and Indian Creek tributaries in 2007, followed by a treatment on McDermitt Creek in 2008) to remove non-native trout and reconnect this population to McDermitt Creek was ineffective due to a failed chemical treatment and/or illegal non-native rainbow and brook trout translocation(s) (ODFW 2022). Over the last several years, interagency partners have been planning another chemical treatment for the McDermitt Creek Complex. In response, Western Rivers Conservancy (WRC), a conservation-oriented non-profit organization, purchased the main private property in the watershed in late 2020; in 2021, the States of Nevada and Oregon were awarded a Section 6 Land Acquisition Grant (Melcher 2022) to purchase the property from them in the next two years. It is expected that a chemical treatment will occur in the coming years to remove non-native trout from the McDermitt Creek Complex and allow for the formation of a resilient LCT recovery population that displays meta-population dynamics; this would fulfill the 3rd updated objective for the QMU within the next 10–20 years.

The LCT populations within Washburn, Crowley, and Jackson Creeks are unlikely to be resilient but lack straight-forward management options like the previously discussed populations. Washburn and Crowley Creeks flow east from the Montana Range (Figure 9C); the populations within these small, headwater systems have experienced declining abundances over the last two decades likely because water availability and habitat quality have decreased through time. Currently, Jackson Creek is the only stream system in the Jackson Range with an LCT population. The primary limiting factors in this system its lack of complexity and springs which flow through the tailings at the Iron King Mine on site that could potentially be causing water quality impacts (Byrne 2017). Nevertheless, these populations, in combination with the others described above, need to be maintained until the LCT GMP is completed (and in accordance with the 5th updated conservation objective); based on guidance developed within this document, the 2019 UGOs can be updated to better clarify how these populations fit into the recovery equation *via* the formal Recovery Plan revision process.

Lastly, the LCT recovery populations in Battle (mostly in the North Fork) and Colman Creeks (Figure 9C) ranked in the middle of the potentially resilient category (Table 2). These relatively large systems seem to contain more climate-resilient habitat and are currently in particularly good condition (Jones 2017, McMillan 2021). Genetic health metrics, namely effective population size and diversity, can likely be bolstered in Battle Creek through assisted migration and mitigating seasonal barriers by translocating fish throughout the stream system, increasing the resiliency of this population in the near-term. Wild horse management within the Calico Herd Management Area (HMA) could result in improved riparian habitat conditions, and subsequently improved demographic conditions, for LCT in Colman Creek. If those heightened metrics were maintained through time, and genetic health metrics could be bolstered as well, this and the Battle Creek population could likely move into a state of resiliency over the next 5 to 10 years. Securing these populations, in combination with the other efforts and populations described above, most noticeably moving McDermitt Creek forward, would dramatically increase the resiliency of the QMU and at least help to meet the 4th updated objective; currently, however, only the 5th objective is being met, and only partially as two populations have been lost in the last three years.


**Figure 9C.** LCT occupied habitat within the Quinn Management Unit.

## Reese Management Unit (RMU)

The updated objectives for LCT in the Reese Management Unit (RMU) are:

1. Remove threats (*i.e.*, competition, predation, hybridization) associated with non-native trout species to allow for the formation and/or maintenance of RMU LCT populations identified in RMU objectives 3–5; and
2. Ensure all habitats required to meet RMU objectives 3–5 function ecologically. In some cases, this may require restoration and/or management changes; and
3. Establish meta-population dynamics in at least 1 recovery population; and
4. Maintain at least 1 additional recovery population that is spatially separated from the meta-population that is required by RMU objective 3; and
5. Maintain existing, isolated populations (including the out-of-historical-range populations) that cannot individually meet the recovery population benchmarks provided in the 2019 UGOs. Actively manage those populations together based on guidance provided in the pending LCT Genetics Management Plan to result in at least 1 additional recovery population.

There are currently six potential LCT recovery populations in the RMU, however, none of them are resilient (Figure 10C). Five of the six populations (Crane Canyon, Marysville, Mohawk, Tierney, and Washington Creeks) are unlikely to be resilient due to low metrics in nearly every category (see Table 2 in review text above); if it were not for high hybridization status scores, these populations would have been classified as at risk of extirpation. For example, Tierney Creek LCT have been outcompeted by non-native brook trout and the last electroshocking survey produced no LCT; eDNA analysis was used in 2021 to confirm that LCT are still present, but at very low densities (NDOW, 2021b). Although the other four populations do not contain non-native trout currently, they are in small headwater stream habitat fragments that are in relatively poor to moderate condition (Starr, 2016a, Starr 2016b, Starr 2017); however, very little quantitative habitat condition data are available at present. These populations likely cannot be resilient unless land management activities result in improved habitat conditions, and they are actively managed as a "population unit" using assisted migration (see description above in the QMU); guidance for how this may be accomplished will be within the pending LCT GMP. Regardless, these five LCT populations, in combination with the maintenance of the two out-of-historical-range populations on the east side of the Toiyabe Range in Santa Fe and Shoshone Creeks (Figure 10C), continue to partially meet the 5th updated conservation objective.

The remaining LCT population is within San Juan and Cottonwood Creeks and was categorized as potentially resilient (Table 2) due to low genetic metrics and a moderate abundance score. This population is within approximately 10.5 interconnected stream miles that can likely become more resilient by improving habitat conditions and bolstering genetic metrics through assisted migration with other pure RMU populations. It is currently unclear how much effort it would require improving riparian habitat conditions within this population. It is clear, however, that building functional relationships among rightsholders and stakeholders in this LMU is essential to accomplish anything meaningful for LCT. Currently, rightsholder and stakeholder engagement activities and relationships are tenuous at best. With guidance still pending for how to best manage the genetics of these (and other) populations to increase resiliency metrics, and the lack of functioning partnerships in this LMU, it is unclear whether these population’s status will improve soon.

None of the other RMU updated objectives have been accomplished at this time. To complete the updated conservation objectives, especially the 3rd objective where only the upper Reese River is an option, it is imperative to improve rightsholders and stakeholder relationships over the next several years. For example, the upper Reese River Project was completely permitted and funded last year (including land boundaries moved to facilitate the construction of an improved irrigation diversion/fish barrier for a rightsholder, funding procured, and National Environmental Policy Act (NEPA) determination competed), but poor relationships forced interagency partners to halt the non-native fish removal activities because several rightsholders suddenly opposed the project. The priority for this LMU is to develop functional relationships with stakeholders prior to the next Status Review so that meaningful projects are possible in the future.

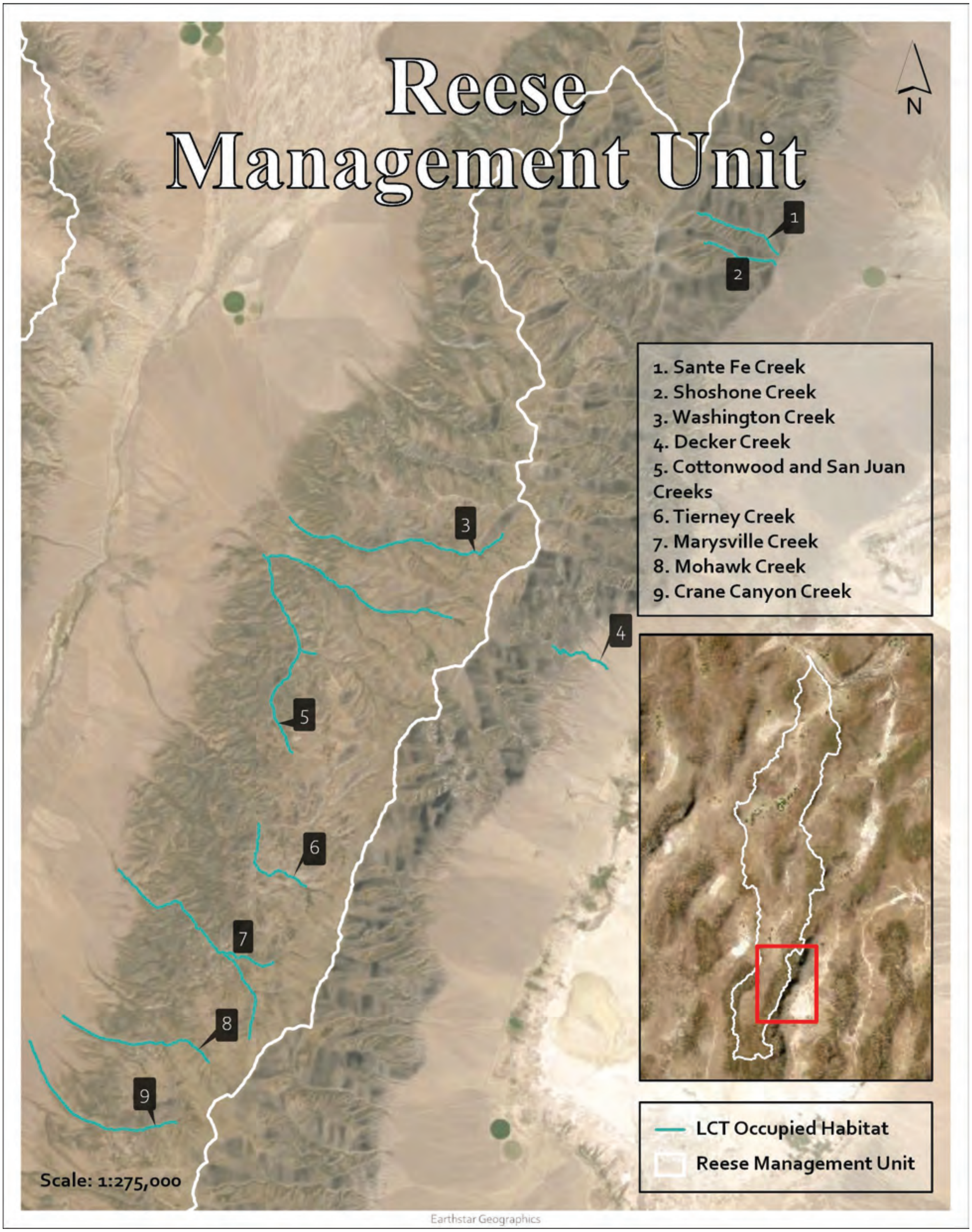


**Figure 10C.** LCT occupied habitat within the Reese Management Unit.

## Summit Management Unit (SMU)

The updated conservation objectives for LCT in the Summit Management unit (SMU) are as follows:

1. Manage and minimize threats from non-native species to improve the resiliency of the SMU LCT recovery population; and
2. Ensure that all habitats that support the SMU recovery population are managed to function ecologically. In some cases, this may require restoration and/or management changes; and
3. Continue management of the recovery meta-population within Summit Lake and its tributaries to improve resiliency.

The recovery meta-population in Summit Lake and its tributaries (Figure 11C) is currently the most resilient LCT population range wide (see Table 2 in review text above). This LMU fully meets the updated conservation objectives recommended in the 2019 UGOs at this time; this is the only LMU that currently meets all its updated objectives. Nonetheless, climate change (drought) and invasive riparian vegetation pose significant challenges to maintaining its resiliency because they threaten to reduce connectivity in the watershed. Climate change and the ongoing decline in lake level may sever the creek from the lake more regularly in the future, thus reducing the productivity of the spawning run. In addition, invasive reed canary grass may be contributing to creek channelization, which may be disconnecting the creek from the floodplain and degrading instream and riparian habitat. Continued effort to maintain fish passage and restore the riparian corridor are needed, as is also required by the updated conservation objectives.

The SMU currently has another potential LCT recovery population in Snow Creek (a tributary to Summit Lake), which is anthropogenically disconnected from the lake (Figure 11C). Snow Creek contains an isolated LCT population that is unlikely to be resilient on its own because the habitat fragment is too small and contains only a low number of fish; reconnecting it to Summit Lake would likely increase the resiliency of the Summit Lake recovery population by increasing the amount of tributary and spawning habitat and its overall climate-resiliency. This and other future conditions information related to climate-change and habitat conditions will be better collated and analyzed in the pending SSA/formal Recovery Plan revision process.

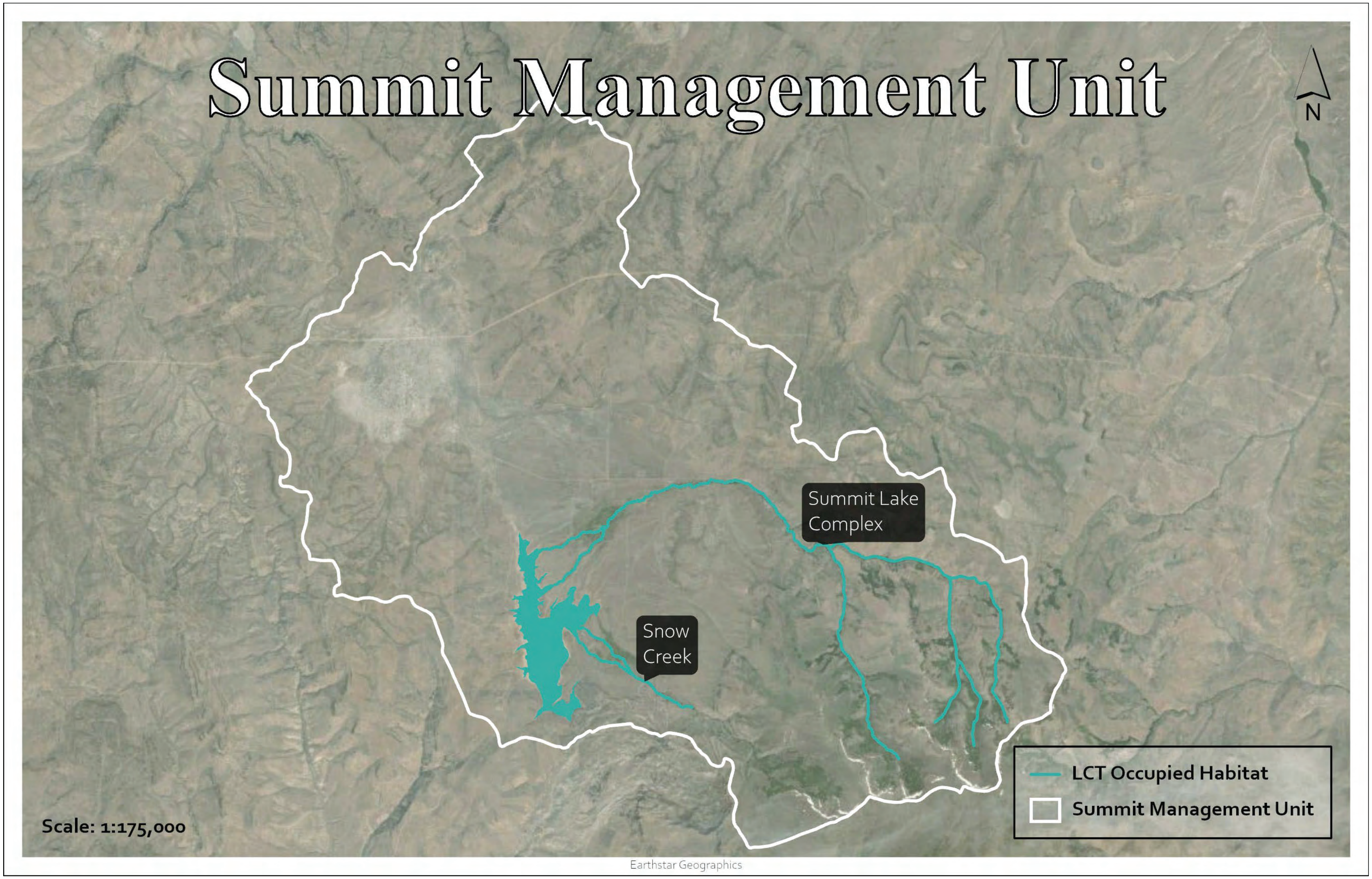


**Figure 11C.** LCT occupied habitat within the Summit Management Unit.

## Walker Management Unit (WMU)

The updated objectives for LCT in the Walker Management Unit (WMU) include:

1. Manage and minimize threats (*i.e.*, competition, predation) and hybridization risk from non-native trout species to allow for the formation and/or maintenance of WMU LCT populations identified in WMU objectives 2–5; and
2. Establish meta-population dynamics within at least 1 recovery population; and
3. Establish (or maintain) 3 additional recovery populations that are spatially separated from each other, and the meta-population required by WMU objectives 2; and
4. Ensure at least 1 of the 4 recovery populations required by WMU objectives 3 or 4 is in a system with a lacustrine component; and
5. Maintain existing, isolated populations that cannot individually meet the recovery population benchmarks provided in this document. Actively manage those populations together based on guidance provided in the pending LCT Genetics Management Plan to result in at least 1 additional recovery population; and
6. Improve habitat conditions throughout the Walker River Basin, and water inflow to Walker Lake, to provide for the future opportunity to reintroduce a lacustrine LCT population into Walker Lake.

There are currently seven potential LCT recovery populations in the WMU (Figure 12C). All populations within this unit were ranked as potentially resilient, with scores between 2.0 and 2.8 (see Table 2 in review text above). In general, these populations contain low to moderately low genetic metrics and abundances; this is logical considering all these populations were founded with individuals from one, small headwater stream population in By-Day Creek (Finger *et al.* 2018) and are still isolated within relatively small habitat fragments. However, three of these seven populations are unlikely to be resilient (By-Day, Murphy, and Cottonwood Creeks) because these populations exist in stream fragments that are limited by barriers or water availability; this prevents connection to other habitats and thus they do not contain the habitat size or complexity to allow for the development of a resilient population on their own. Even so, they contain LCT and are to be maintained per the 5$^{th}$ updated conservation objective (also see summaries below for more insight). Habitat restoration work is continuing within By-Day Creek to improve drought resiliency. Efforts to improve habitat conditions throughout the Walker River watershed, and water inflow to Walker Lake, are ongoing. At present, restoration activities are occurring throughout the watershed and 53% of the water needed to restore the lake has been acquired (https://www.walkerbasin.org/). However, it is unclear when Walker Lake will be restored enough to contain an LCT population. Beyond maintaining populations that existed in 2019 (the 5$^{th}$ updated objective), none of the other objectives for the WMU have been satisfied at this time.

Of the remaining four populations, all could potentially be resilient in the future, albeit with differing levels of management and effort. Mill and Wolf Creeks ranked on the higher end of the potentially resilient category (2.8 and 2.6, respectively), with high abundances and age-class metrics, and no indication of hybridization. However, the effective population sizes and diversity metrics are low to moderately low for these populations; similar data were observed for all populations in this watershed (and most across the range). It is logical, with guidance pending from the LCT GMP, to assist migration between pure LCT populations within this LMU to determine if the genetic metrics can be improved and maintained. The main goal would be to move these populations into a resilient state relatively easily through genetics management over the next five years or so.

Silver Creek and the majority of Slinkard Creek contain non-native trout that must be removed for them to become resilient; the upper mile of habitat in Slinkard Creek contains a pure LCT population free of non-natives due to a large fish barrier. Interagency efforts over the last decade to mechanically remove non-native brook trout from Silver Creek have failed, but recent efforts include dewatering to improve the success of mechanical removal. This tactic has been successful in other eastern Sierra Nevada habitats and resulted in substantive gains for other native fish species. Slinkard Creek requires the retrofitting of an existing fish barrier lower down in the system to keep non-native trout out of the population; plans are currently being permitted and the project is fully funded, so this should occur within the 2 years. Once the lower barrier is retrofitted, the removal of non-native trout from this system will need to occur, probably using methods like Silver Creek, described above. It will likely take about 5 years to complete these projects; thus, with guidance from the pending LCT GMP, these populations could reach a state of resiliency within the next 5–10 years. None of the populations described above have the potential to meet the 2$^{nd}$ or 4$^{th}$ updated objectives; however, the 4 potentially resilient populations discussed here can satisfy the 3$^{rd}$ objective and push the WMU into a good position within the next 10 years.

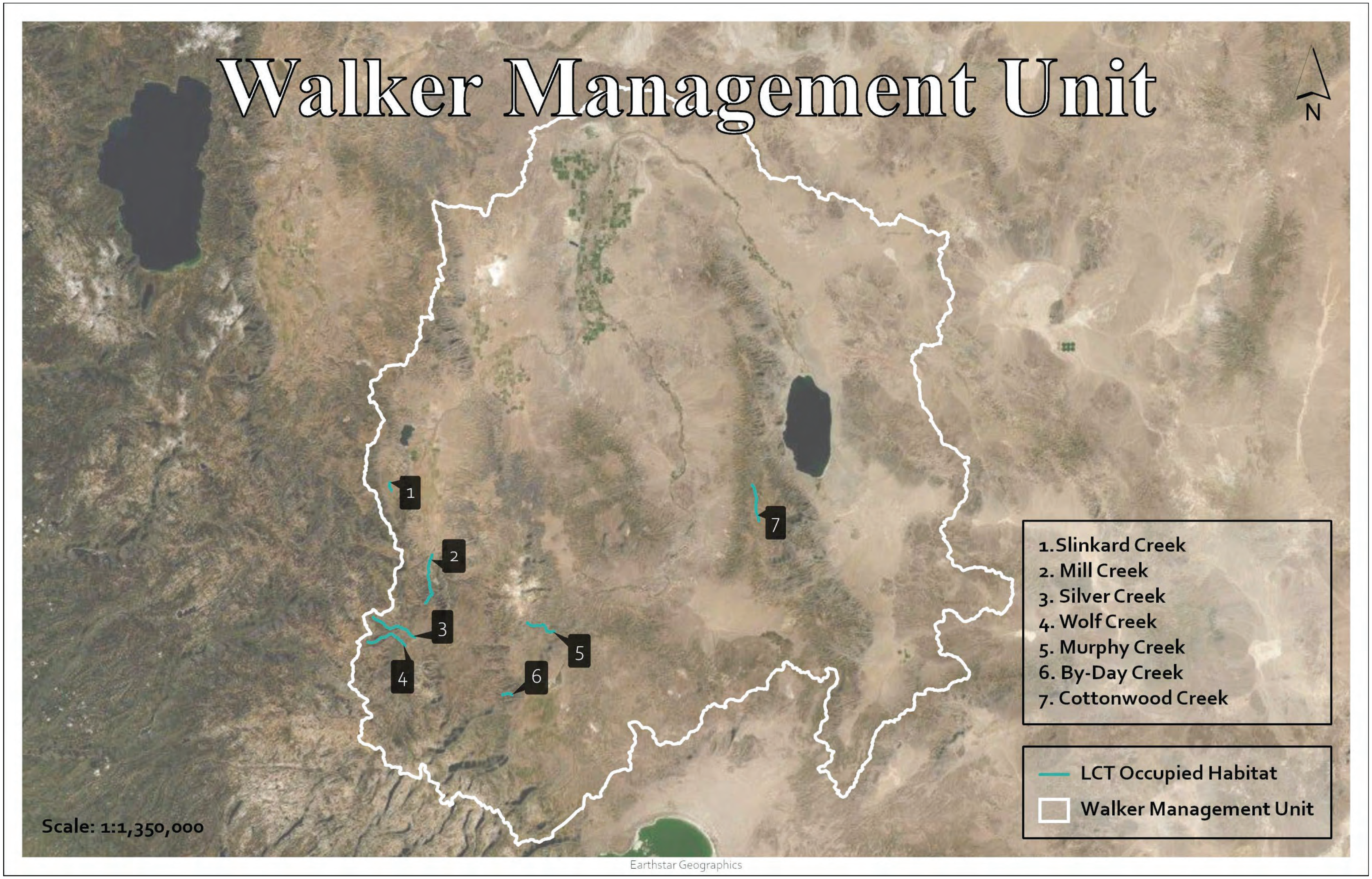


**Figure 12C.** LCT occupied habitat within the Walker Management Unit.

## Willow-Whitehorse Management Unit (WWMU)

The updated objectives for LCT in the Willow-Whitehorse Management Unit (WWMU) are:

1. Remove threats (*i.e.*, competition, predation, hybridization) associated with non-native trout species to allow for the formation and/or maintenance of WWMU LCT populations identified in WWMU objectives 3–5; and
2. Ensure all habitats required to meet WWMU objectives 3–5 function ecologically. In some cases, this may require restoration and/or management changes; and
3. Maintain meta-population dynamics in the Whitehorse Creek recovery population; and
4. Maintain the recovery population within Willow Creek; and
5. Maintain existing, isolated populations and the out-of-historical-range populations in the Steens Mountains, and actively manage them (adopting guidance from the pending LCT Genetics Management Plan) to increase long-term persistence probabilities for use in augmenting Willow and Whitehorse Creek recovery populations as needed.

The WWMU currently contains three potential LCT recovery populations, and four out-of-historical-range populations in the Steens Mountains (Figure 13C) that contain LCT that originated from Willow and Whitehorse Creeks (Peacock *et al.* 2010, ODFW 2022). Overall, this LMU is relatively stable, with potentially resilient populations in both Willow and Whitehorse Creeks (see Table 2 in review text above), and relatively robust, but isolated redundant populations in the Steens Mountains (ODFW 2022); data are currently being collected and compiled for those populations in the Steens Mountains and were not yet available for this review. However, the LCT population in Antelope Creek is at risk of extirpation, with abundances in the teens to single digits during drought years; only a small portion of the stream, near a spring complex, appears to stay wetted in drought years according to recent field surveys.

The 1st updated conservation objective for the WWMU has been potentially satisfied: non-native trout do not appear to be a threat to any of the potential LCT recovery populations recommended by the 2019 UGOs. Recent genetic samples will be used to confirm this in the next year or so. Moreover, the last updated objective for this LMU continues to be met, although it should be revised during the formal Recovery Plan revision process given the status of Antelope Creek and pending guidance from the LCT GMP. Willow and Whitehorse Creeks were at the high end of the potentially resilient category (2.8) because of low effective population sizes and genetic diversity metrics; to increase the resiliency of populations and satisfy the remaining conservation objectives, several simple, yet important actions should occur. First, connectivity issues within the Willow Creek population need to be addressed; potential solutions include restoring the stream to bypass the existing headcut, or to assist fish movement above the headcut manually, to allow for gene flow upstream of the barrier. Similarly, both populations would likely benefit from assisted migration between each other and the populations within the Steens Mountains pending guidance within the LCT GMP and confirmation of the hybridization status of all the existing populations. These actions should be tracked to determine if they result in the desired improvement in genetic health and the increased resiliency of the populations; this is something that can easily happen and should be attainable in the next five years or so.


**Figure 13C.** LCT occupied habitat within the Willow-Whitehorse Management Unit.

## TRUCKEE RIVER WATERSHED MANAGEMENT UNITS

This watershed is divided into three LCT Management Units: Independence, Pyramid-Truckee, and Tahoe (See 2019 UGOs for more information). A total of six populations are managed for research and/or recovery purposes: Independence Lake and Creek, Pyramid Lake and Truckee River, Pole Creek, Lake Tahoe, Fallen Leaf Lake, and Upper Truckee River/Meiss Meadow (Figures 14C). These LMUs are unique in that LCT are frequently stocked in several water bodies by Lahontan National Fish Hatchery (LNFH), several State hatcheries, and Numana Fish Hatchery, often for differing purposes. Currently, only one of the potential LCT recovery populations in these LMUs is resilient (Upper Truckee River/Meiss Meadow), with the remaining populations falling into a potentially resilient category due primarily to the presence of non-native trout and the maintenance of demographic and genetic health metrics through stocking programs, not natural reproduction.


**Figure 14C.** LCT occupied habitat within the Truckee River LMUs.

## Independence Management Unit (IMU)

The updated conservation objectives for LCT in the Independence Management Unit (IMU) are:

1. Remove threats (*i.e.*, competition, predation, hybridization) associated with non–native trout species to allow for the formation and/or maintenance of IMU LCT populations identified in IMU objectives 2–4; and
2. Maintain the recovery population within Independence Lake; and
3. Establish at least 1 additional recovery population within the Little Truckee River hydrologic unit that displays meta-population dynamics; and
4. Maintain the Heenan Lake population and actively manage it, in line with the pending LCT GMP, to increase long-term persistence probability and for use in augmenting the recovery populations within the IMU as needed.

The IMU contains 1 potential LCT recovery population within Independence Lake and Creek (Figure 15C; see Table 2 in review text above), which is potentially resilient currently. This population is potentially resilient because of a recent hybridization event (*circa.* 2012) with non-native rainbow trout; putatively, a small number of these fish entered the system when the velocity barrier (high water flow at the dam outlet) was removed for dam maintenance activities and non-native fish from the outflow stream below the lake made it upstream into the lake. Currently, approximately 5 percent of LCT that participate in the spawning run are hybridized, but the other 95 percent are still pure (Barnes 2022). Over the last two years, hybridized individuals have been removed from the system during the spawning season and only pure LCT have been passed above a temporary weir structure to spawn. So far, this has reduced the percentage of hybridized individuals from 11 percent of the spawning run in 2019 to 5 percent in 2021 (Barnes 2022). Over time, this strategy should allow for the removal of all hybridized LCT from the population, pending continued sufficient funding, and thereby reducing the possibility of hybridization and resulting in a more resilient LCT population. However, it will be imperative that an agreement is formed with water managers to better control upstream fish movement below the dam to ensure non-native trout are not able to enter the lake again in the future or the threat is still present and this LMU cannot recover.

Heenan Lake is within the Carson River watershed (Figure 1C) and currently contains an LCT population managed for recreational sportfish production; each year, fish are artificially spawned, and fertilized eggs are taken to several hatchery facilities to be grown out. Fingerlings to catchable LCT are then stocked throughout the eastern Sierras for the sole purpose of meeting the needs of recreational anglers. This population meets the 4$^{th}$ updated objective for the IMU however. This population is included within the IMU because the fish within Heenan Lake are originally from Independence Lake and Creek and still very closely align with that population genetically (Peacock and Kirchoff 2007, Somer 2008). However, this population has been managed for recreational stocking purposes, not recovery/conservation, and thus the genetic health of this population needs to be further explored. Pending guidance from the LCT GMP will include updated genetic information related to this population, refining the vision for how it fits into meeting recovery goals and objectives in the future. No other IMU updated conservation objectives are satisfied at this time.

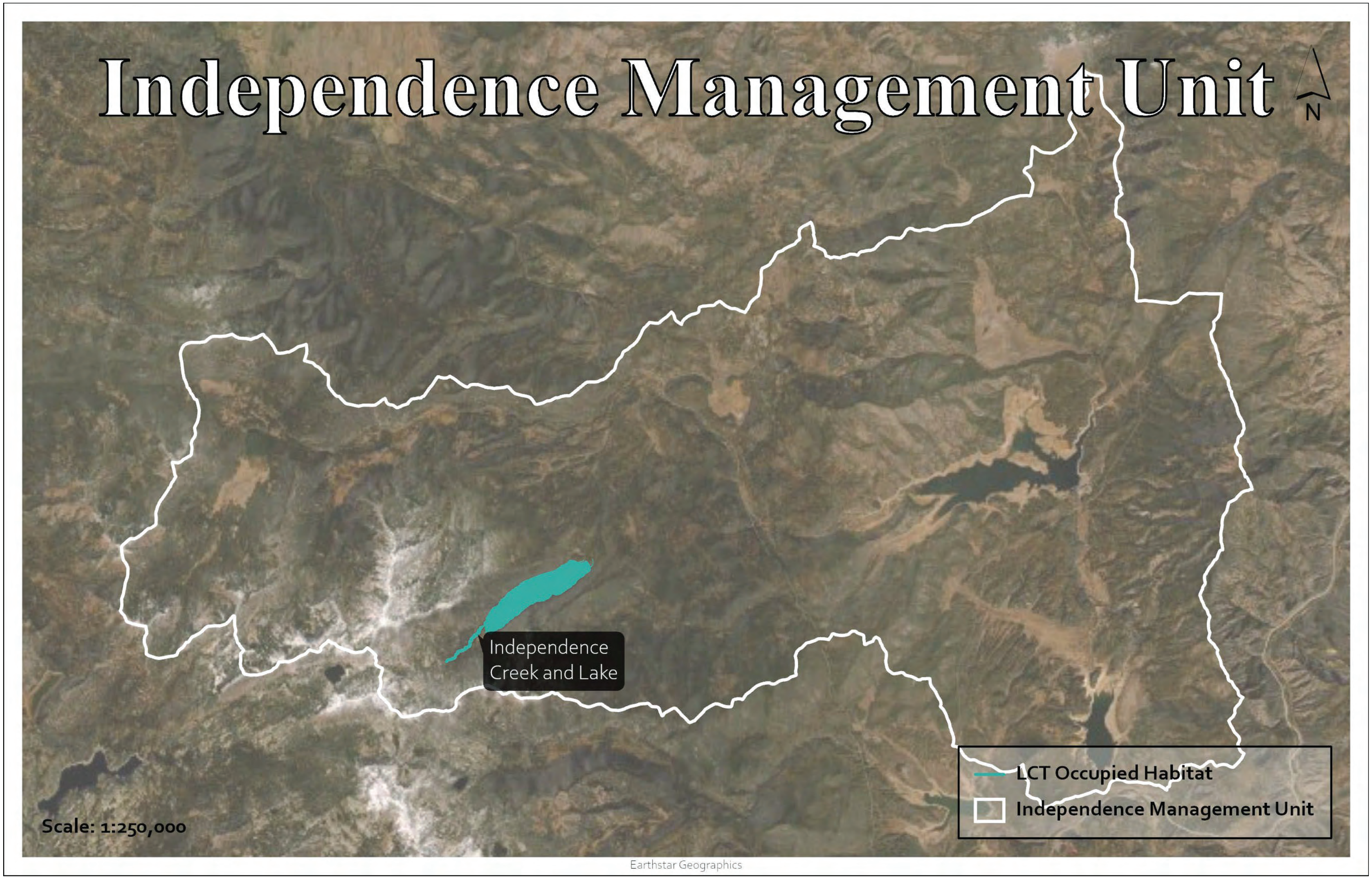


**Figure 15C.** LCT occupied habitat within the Independence Management Unit.

## Pyramid-Truckee Management Unit (PTMU)

The updated objectives for LCT in the Pyramid-Truckee Management Unit (PTMU) are:

1. Manage and minimize threats (*i.e.*, competition, predation) and hybridization risk from non-native trout species to allow for the formation and/or maintenance of PTMU LCT population identified in PTMU objective 3; and
2. Manage watershed connectivity and habitat in Truckee River by addressing fish passage barriers and improving inflow to Pyramid Lake to provide spawning, rearing, and residency opportunities; and
3. Establish a recovery population in Pyramid Lake and the Truckee River.

The PTMU currently contains two potential LCT recovery populations (Figure 16C; Table 2 within review text above), both of which were classified as potentially resilient. The first is within Pyramid Lake and Truckee River, which is actively managed by interagency partners to allow for recovery while also maintaining a popular sport-fishery. This population is classified as potentially resilient for several reasons. First, although spawning runs have been occurring in the lower river for decades, broodstock management of the strain identified as most closely related to known museum samples collected from individuals prior to extirpation in the 1930's, began in the 1990s. Recovery partners began stocking that strain into Pyramid Lake in 2006. In 2012, natural spawning of this strain in the lower Truckee River was first documented. Thus, this population is in the early phase of reestablishment and relies on continued LCT stocking activities in the lake for persistence. However, because natural reproduction has been documented, studies are underway to monitor the potential recruitment into the adult population in Pyramid Lake of these native strain individuals (L. Heki, pers. comm. 2022). The spawning run is managed at Marble Bluff Fish Passage Facility and Research Station located near the terminus of the Truckee River up to Derby Dam; active management, in perpetuity, of this system will likely be necessary to not only reestablish a recovery population here, but also to maintain it. The threat of hybridization with non-native rainbow trout is currently being evaluated (Al-Chokhachy *et al.* 2020). To gain access to the upper portions of the Truckee River at the California-Nevada border, multiple existing structures will have to be retrofitted to allow for fish passage. These projects are designed, planned, and partially permitted and will begin as soon as funding becomes available for them. Many decades of efforts continue to contribute to an improved status of this population through time; however, more work related to addressing the threats from non-native trout and habitat fragmentation is required before this population can become resilient.

Secondly, Pole Creek is a tributary stream to the mainstem Truckee River (Figure 16C) and was classified as a potentially resilient LCT population because of lower abundance and effective population size metrics (Table 2). This population was founded in 1977 with 81 LCT from Macklin Creek, an out-of-historical-range population, which records suggest was established with trout from the Lake Tahoe watershed in the early 1900s, after multiple rotenone treatments to remove non-native trout (Service 2009). This population is protected from reinvasion of non-native trout by a barrier upstream of the confluence with the Truckee River; this provides the population with approximately 1.8 miles of headwater stream habitat that is in good condition overall. Interagency partners have a legacy of efforts to protect riparian habitat and watershed health in this subbasin; there are no real options remaining that can be undertaken to improve this population’s resiliency beyond its current ranking. It is unclear how the Pole Creek population fits into the recovery equation at this time; this is something that needs to be addressed within the pending LCT GMP and through the formal Recovery Plan revision process. Regardless, although progress is being made to meet updated conservation objectives for the PTMU, none have been completed at this time.


**Figure 16C.** LCT occupied habitat within the Pyramid–Truckee Management Unit.

## Tahoe Management Unit (TMU)

The updated conservation objectives for LCT in the Tahoe Management Unit (TMU) are:

1. Manage and minimize threats (*i.e.*, competition, predation) and hybridization risk from non-native trout species to allow for the formation and/or maintenance of TMU LCT populations identified in TMU objectives 2 and 3; and
2. Establish multiple lacustrine recovery populations within the unit, including in Lake Tahoe; and
3. Continue management of the meta-population within Upper Truckee River/Meiss Meadow and adopt guidance from the pending LCT Genetics Management Plan.

The TMU contains three potential LCT recovery populations currently (Figure 17C; Table 2 within review text above). The first is within Upper Truckee River/Meiss Meadow, which is a likely resilient, interconnected fluvial/adfluvial population with on-going management of the threats from non-native trout (see Table 2 in review text above). The LCT in this population originated from Macklin Creek *via* a reintroduction effort facilitated by the Forest Service in 1989 and 1990 (Lemmers and Santora 2012). Non-native trout have been removed from most portions of Meiss Meadow habitat (approximately 5.5 stream miles), and that portion is partially protected from reinvasion by natural fish barriers that largely prevent upstream fish movement (Lemmers and Santora 2012). Recent work to continue non-native trout removal below those natural barriers will increase this population's resiliency in the future. In addition, genetic health metrics can likely be bolstered through time once non-native trout are managed to an acceptable level; guidance for how to best do this will be within the pending LCT GMP. Lastly, it will also be important to better clarify the role of this population in the formal Recovery Plan revision process. Currently, this population is fulfilling the 3$^{rd}$ TMU updated objective.

Fallen Leaf Lake is a population connected to Lake Tahoe *via* Taylor Creek, an outflow stream (Figure 17C); it is mostly fed by Glen Alpine Creek, which has a relatively large upstream watershed. Substantial efforts have occurred here since 2002 to reestablish an LCT population that provides research opportunities and recreational angling; this population was ranked as potentially resilient because there is still limited spawning habitat due to a large natural barrier and the threat of hybridization with non-native rainbow trout is present throughout Glen Alpine Creek. This LCT population is currently maintained entirely through fish stocking activities. With a substantial, multi-year effort, this population could become resilient by managing non-native trout in the upper watershed; currently, however, no plans are in place to do so, making it unlikely that this population will be resilient in the coming years.

Recent efforts have been made to reintroduce an LCT population into Lake Tahoe (Figure 17C), the largest and most climate-resilient lake within its historical range. Reintroduction efforts of the strain identified as the most alike to museum samples collected from individuals prior to extirpation in the 1930's, began in 2011 and 2019, and is largely focused on recreation and research at this point. Interagency partners recently completed a collaborative fish stocking plan to guide management activities (LNFH 2022). However, there are limited data available for this population since it is in the early phases of reestablishment and is solely dependent on stocking currently. Recent increases in stocking and funding for research and monitoring will help to inform management decisions and an assessment of resiliency for the LCT population in Lake Tahoe in the future.


**Figure 17C.** LCT occupied habitat within the Tahoe Management Unit.