U.S. Fish and Wildlife Service

# Bull Trout Recovery Planning

*Final Report – FY 2016*

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***On the cover:*** *Aggregation of mature bull trout staging before spawning. Photo courtesy of Joel Sartore – National Geographic Stock with Wade Fredenberg.*

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*Abstract* – In 1999, bull trout (*Salvelinus confluentus*) were listed as threatened under the Endangered Species Act. From 1999-2015, staff at the Columbia River Fisheries Program Office were involved in numerous aspects associated with developing a Recovery Plan for bull trout. An initial draft recovery plan was published between 2002 and 2004. Public comment on this draft centered over concerns about 1) Distinct Population Segment (DPS) structure and 2) recovery criteria. Recovery planning was postponed in 2005. A 5 year review of bull trout status was completed in 2008 and bull trout remained listed as threatened. In 2008 and 2012, the Recovery Monitoring and Evaluation Group, formed in response to Chapter 1 of the draft recovery plan, produced documents to help guide monitoring and evaluation associated with bull trout recovery. In 2010, a revised analysis of bull trout population structure led to a modification of Recovery Unit Structure and, ultimately, the DPS. In 2010, critical habitat was redesignated for the third (and final) time. In 2012, an approach to assess the biological viability of bull trout Recovery Units, based in part on demographic information, was developed to support and guide the finalization of recovery criteria. Shortly after this, the requirement to use demographic information to evaluate recovery was abandoned. In 2015, a final, threats-based, recovery plan for bull trout was published. The final plan focuses on identifying and effectively managing primary threats in each recovery unit. The monitoring and evaluation that is necessary to support future 5-factor analyses and listing decisions is unclear and has not been determined.

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# Introduction

Bull trout (*Salvelinus confluentus*) is an imperiled species of char native to the Pacific Northwest. Combinations of numerous factors, including habitat degradation (e.g., Fraley and Shepard 1989), barriers to migration (e.g., Rieman and McIntyre 1995), and the introduction of non-natives (e.g., Leary et al. 1993), have led to the decline of bull trout populations across their native range (Rieman et al. 1997). Consequently, bull trout in the coterminous United States were petitioned for protection under the Endangered Species Act (ESA), and listed as threatened on November 1, 1999 (64 FR 58910) (USFWS 2002). Because bull trout were considered threatened across their entire range, which occurred in contiguous states, they were listed under the ESA as one, coterminous, Distinct Population Segment (DPS). As a result of this listing, the U.S. Fish and Wildlife Service (USFWS) was charged with designating critical habitat, conducting 5-year reviews, and developing a federal recovery plan for bull trout.

# Recovery Planning, Phase I (circa 1998-2004)

The first phase of recovery planning occurred between 1998-99 and 2002-04. Bull trout throughout their range were divided into 27 Recovery Units. As such, an introductory chapter (Chapter 1) and 27 Recovery Unit chapters were developed as a draft Recovery Plan (USFWS 2002, 2004). Staff at USFWS – Columbia River Fish and Wildlife Conservation Office (CRFWCO) served as the lead authors on 13 of these Recovery Unit chapters and as contributing authors to Chapter 1. These draft plans were published in the Federal Register and made available for public comment. The most significant comments received from the public review questioned the appropriateness of 1) bull trout being organized into and evaluated as one DPS (or the population structure of bull trout that had been characterized by the USFWS) as well as 2) the specificity and utility of the recovery criteria (which were focused on relatively prescriptive, numerical thresholds). In addition, Chapter 1, in particular, called for the development of monitoring and evaluation guidance to inform the assessment of recovery criteria. In response to this directive, CRFWCO formed a Recovery Monitoring and Evaluation Group (RMEG) who, in turn, developed and published two guidance documents (USFWS 2008a, 2012). These documents provided guidance on monitoring local populations (or patches) of bull trout as the fundamental unit for evaluations of occupancy/ distribution, connectivity, trends in abundance and abundance.

# Recovery Planning, Postponed (circa 2005-2010)

In 2005, recovery planning efforts were postponed. The postponement was largely due to the court-ordered need for the USFWS to reconsider critical habitat designations and complete a mandatory 5 year review. Both of these tasks were deemed the highest priority relative to the bull trout listing.

Routine 5 year reviews are required by the ESA for all listed species. The initial 5 year review for bull trout began in 2004-05. It involved multiple staff from CRFWCO providing reviews, participating with expert panels, working with partners as well as modifying and applying IUCN assessment procedures (e.g. NatureServe) toward the 5 year review. The assessment rated threats and demographic information to categorize population risk and status of core areas across the coterminous range of bull trout. The review was completed in 2008. One, coterminous DPS of bull trout remained listed as threatened (USFWS 2008b).

*http://www.fws.gov/pacific/bulltrout/pdf/Bull%20Trout%205YR%20final%20signed%20042508.pdf*

Subsequent tasks required the USFWS to review the appropriateness of the population structure that had been determined for bull trout (one major comment that was received when the 2002-04 draft Recovery Plan was published in the Federal Register). Staff from CRFWCO participated in the process by delivering existing data and information on population structure to the review process, collecting new information, and providing analytical support. As suggested by the integration of multiple lines of evidence, the USFWS identified six units of bull trout that were likely discrete and significant (see Ardren et al. 2011). A map of these units is located at:

*http://www.fws.gov/pacific/bulltrout/images/maps/rangewide.jpg*

Bull trout from within a given unit appeared to share an evolutionary legacy and future. Although it was probable that each of these units were destined to become their own individual DPS, for administrative purposes, they remained classified as Recovery Units. Thus, one, coterminous DPS of bull trout that had originally been divided into 27 recovery units was now divided into six Recovery Units that, essentially, represented six DPSs.

After the 5 year review was complete and population structure reconsidered, redesignating critical habitat became the focus of the USFWS. Although critical habitat had originally been designated in 2002-03, then revised in 2004, there was a legal need to revisit these designations. Staff from CRFWCO provided 1) information on the occupancy and distribution of bull trout, 2) guidance on consistent and scientifically defensible approaches to determining critical habitat and 3) GIS support for mapping and final critical habitat determination. The redesignation of critical habitat was completed in 2010 (USFWS 2010), and now includes the mainstems of the Columbia and Snake rivers.

## Recovery Planning, Phase II (circa 2010-2012)

Recovery planning recommenced in 2010. The most significant issue that remained for finalizing a recovery plan revolved around the comments received on the appropriateness of the recovery criteria that had been published in the draft Recovery Plan. This issue emphasized the need to have a plan that presented criteria that 1) were not prescriptive of specific actions that were required to 2) achieve specific numbers or thresholds but, rather, would allow managers to understand clearly 3) what was necessary for recovery to be achieved and how it would be assessed.

Working closely with the Bull Trout Technical Team (BTTT), staff at CRFWCO helped to craft a proposal to accomplish the goals associated with improved criteria. Briefly, the approach was to use an existing tool that had been accepted by comanagers for evaluating core area status (USFWS 2008b), integrate these evaluations to assess the biological viability of a given Recovery Unit, and in turn use the information on biological viability to inform evaluations of recovery and decisions about delisting. To accomplish this, staff at CRFWCO were integrally involved in developing a Viability Rule Set (VRS) for bull trout populations.

CRFWCO staff and the BTTT established the VRS by using the NatureServe status assessment approach which had been adapted to evaluate the status of core areas. This approach had been vetted and approved by partners during the 5 year review and USFWS partners requested consistent use of this tool by the USFWS in future assessments. The VRS was developed to integrate core area information in a manner that allowed the biological viability of an entire recovery unit (composed of multiple core areas) to be assessed. The VRS established viability criteria that were developed to be SMART (Specific, Measurable, Achievable, Realistic and Time-referenced; per recovery planning guidance, NMFS and USFWS 2010), incorporate the 3 Rs (redundancy, resiliency, and representation; per recovery planning guidance, NMFS and USFWS 2010), and use biological viability to support a recovery assessment and delisting determination. Working with the BTTT, staff from CRFWCO provided USFWS decision makers (DMs) with scientific justification and rationale for the VRS (Appendix 1). Although the VRS approach was supported by the majority of USFWS DMs, it was not supported by all DMs and ultimately rejected for use in recovery planning.

## Recovery Planning, Phase III (circa 2012-2015)

The final phase of recovery planning began in 2012. After the VRS approach was rejected, recovery planning became a process that was exclusively directed by the USFWS, Ecological Services (ES) division. The lead in bull trout recovery planning was the ES office in Boise, ID. The Boise ES office worked (primarily) with other ES offices and State partners, formed a State and Federal Management Team (SFMT), and developed a threats-based recovery plan (USFWS 2015). In summary, this plan focused on using professional judgment to identify 1) primary threats to bull trout and 2) how effectively these threats are being managed. The plan proposed to judge recovery based on the effectiveness of threat management and, essentially, recovery criteria ranged from 75-100% (dependent on the Recovery Unit) of primary threats being managed effectively.

The Fish and Aquatic Conservation Program (FACP) of the USFWS had little involvement in phase III of recovery planning. In coordination with the Oregon Fish and Wildlife Office, staff at CRFWCO provided review of the draft plan, prior to it being published in the Federal Register. In summary, major comments were:

- No explicit demographic criteria in the Recovery Plan
- No RM&E plan identified to monitor bull trout to determine whether or not threats have been effectively managed
- The Threats Assessment Matrix in the current draft is unclear and subjective
- Inadequate description for the identification, characterization, definition and management of threats
- Inaccurate description and use of the NatureServe status assessment tool (which was vetted through, and supported by partners)
- Rationale for recovery criteria is unclear (e.g., 75% or 100% of core areas need to have "threats effectively managed")

- The plan greatly deviates from the USFWS' use of the adaptive management approach (Strategic Habitat Conservation) to promote science excellence.

Staff at CRFWCO also provided briefings to FACP Project Leaders as well as the FACP Assistant Regional Director and regional staff.

The final recovery plan for bull trout was published on September 30, 2015. The plan can be found at the following link:

*http://www.gpo.gov/fdsys/pkg/FR-2015-09-30/pdf/2015-24670.pdf*

Concurrent to the finalization of the recovery plan, ES also developed an updated 5 year review for bull trout in 2015. Although the recent 5 year review has not been published on the federal register yet (as of November 16, 2015), the draft suggested that one, coterminous DPS would remain listed as threatened under the ESA.

## Potential Next Steps (circa 2016)

Recovery planning for bull trout has concluded. The potential next steps in the recovery process are to implement recovery actions that are identified in individual Recovery Unit Implementation Plans (included in the final Recovery Plan) as well as monitor and evaluate recovery to inform future 5-factor analyses and listing decisions. Thus, potential next steps for staff at CRFWCO will be to 1) consider publishing the VRS approach for evaluating the viability of a bull trout Recovery Unit (or DPS) as a tool for assessing the efficacy of recovery actions; and 2) provide technical assistance and support in the development of a recovery, monitoring and evaluation plan that would support future 5-factor analyses and listing decisions.

## Acknowledgements

This work occurred over the past 17 years and would not have been possible without the effort and commitment many people that, unfortunately, are too numerous list completely. H. Schaller was the Project Leader at CRFWCO for the majority of this period and provided invaluable orchestration, guidance and wisdom throughout the process. Current or former employees at CRFWCO that had a particular focus on and helped to produce much of this work included T. Cummings, M. Hudson, B. Le, H. Schaller and P. Wilson. In addition, RMEG members (which also fluctuated during this time period) volunteered their time to provide expert guidance on monitoring and evaluation. The work was funded by CRFWCO, OFWO, and Region 1 of the USFWS. The findings and conclusions in this manuscript are those of the authors and do not necessarily represent the views of the U.S. Fish and Wildlife Service.

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# Appendix 1

## Justification of the thresholds used in the viability rule set

### Introduction

The six recovery units within the coterminous range of bull trout are each made up of a collection of core areas, which in turn contain one or more local populations. If a core area contains more than one local population, the core area functions as a metapopulation and its local populations likely interact at some level. The core area is the closest approximation of a biologically functioning unit within the bull trout population structure, and is the basic unit on which to gauge recovery within a recovery unit.

Determining bull trout core area conservation status (i.e., the relative risk of extirpation) is an important part of assessing recovery unit viability. The NatureServe Rank Calculator (NatureServe 2009) is a tool that integrates demographic and threat-based information about each bull trout core area to calculate its relative risk of extirpation. However, recovery viability does not depend alone on the status of bull trout within core areas; the spatial arrangement of core areas and connectivity between them must also be evaluated to determine whether or not the recovery unit as a whole is viable. A viable recovery unit should demonstrate that the principles of biodiversity have been met (i.e., the three Rs):

- **Representation** involves conserving the breadth of the genetic makeup of the species to conserve its adaptive capabilities.
- **Resiliency** involves ensuring that each population is sufficiently large to withstand stochastic events.
- **Redundancy** involves ensuring a sufficient number of populations to provide a margin of safety for the species to withstand catastrophic events.

To ensure that the 3 Rs are preserved within each recovery unit, we developed a method to assess recovery unit viability that integrates the information we have about the status of each core area and the ways in which they interact. The "viability rule set" we developed preserves representation, resiliency and redundancy across each recovery unit and is our best estimate of what recovery units must minimally maintain to be viable. The rule set incorporates core area status as measured using NatureServe, and requires that thresholds be met for general core area stability and the maintenance of representative strongholds.

### Using The NatureServe Methodology To Assess Core Area Risk

The primary purpose of the NatureServe methodology we employed is to conduct status assessments which can be used to evaluate the potential risk of extinction or extirpation of a core area. The NatureServe conservation status assessment methodology considers (1) all data collectively when assigning a status, (2) can produce a range of ranks, (3) is transparent, (4) explicitly considers threats in the assessment, and (5) can be used to assess conservation status for both species and ecosystems (Master et al. 2009). The NatureServe methodology can use inputs from data rich circumstances resulting from relatively rigorous and quantitative assessments as well as inputs from data poor circumstances, or information based on expert opinion (see Faber-Langendoen et al. 2009). For a given unit (i.e. species, state, core area of bull trout) the NatureServe methodology yields a rank score which ranges from 0 - 5.5. Associated with the rank score are five categories of risk (see Table 1). Rank scores of 0 - 1.5 are categorized as "critically imperiled," 1.51 - 2.5 are categorized as "imperiled," 2.51 - 3.5 are categorized as "vulnerable," 3.51 - 4.5 are categorized as "apparently secure" and 4.51 - 5.5 are categorized as "secure" (Faber-Langendoen et al. 2009, Master et al. 2009).

Using The NatureServe Methodology To Assess Bull Trout Core Areas

NatureServe can be applied at many scales including global, national, and subnational. Bull trout core areas are assessed at the subnational scale, which is appropriate considering the large range in size across core areas (515 ha – 1,587,950 ha); in fact, some core areas are larger than entire countries (e.g., the Yakima core area is almost twice the size of Puerto Rico).

As stated above, NatureServe uses inputs that reflect a core area's demographic and threat conditions. If information about a particular parameter is unknown, NatureServe can still generate a rank score. NatureServe inputs for each bull trout core area include: linear distance of occupancy, number of local populations, adult population size, proportion of occupied area in good condition, short-term trend, threat scope, and threat severity. For each demographic parameter, inputs are chosen from multiple bins that increase in size. For example, the bins for population size are: 1-50 adults; 50-250; 250 – 1000; 1000 – 2500; 2500 – 10,000; 10,000 – 100,000; 100,000 – 1,000,000; and greater than 1,000,000 adults. Threat scope and severity are measured by bins having high, moderate, low and insignificant conditions. During the bull trout 5-year review process (U.S. Fish and Wildlife Service 2008), bull trout experts reviewed the bin sizes for each input and determined that the bins were suitable for characterizing bull trout core areas. Thus, the bin sizes were not changed from the original NatureServe Rank Calculator tool.

The NatureServe methodology uses the inputs to generate one rank score for each core area. Rank scores can be anywhere between 0 and 5.5, and correspond to a risk category number (the "S-rank", or subnational rank) and risk status category (Table 1).

**Table 1.** NatureServe rank scores and conservation status ranks for core areas.

| Calculated Rank Score | Risk Category Number | Risk Status |
|---|---|---|
| Calculated value <= 1.5 | S1 | critically imperiled |
| 1.5 < calculated value <= 2.5 | S2 | imperiled |
| 2.5 < calculated value <= 3.5 | S3 | vulnerable |
| 3.5 < calculated value <= 4.5 | S4 | apparently secure |
| 4.5 < calculated value <= 5.5 | S5 | secure |

NatureServe's conservation status rank scores describe the relative risk of extirpation for the entity assessed. Bull trout core area extirpation risk can be defined by using the NatureServe description of each risk status category (Faber-Langendoen et al. 2009):

- Bull trout are **critically imperiled** in core areas where they are extremely rare or where some factor(s) such as very steep declines makes them especially vulnerable to extirpation from the core area.
- Bull trout are **imperiled** in core areas where rarity is caused by a very restricted range, there are very few local populations or occurrences, steep declines, or other factors that make them very vulnerable to extirpation from the core area.
- Bull trout are **vulnerable** in core areas where range is restricted, there are relatively few local populations or occurrences, there have been recent and widespread declines, or if there are other factors that make them vulnerable to extirpation.
- Bull trout are **apparently secure** in core areas where they are uncommon but not rare; in these core areas, there is some cause for long-term concern due to declines or other factors.
- Bull trout are **secure** in core areas where they are common, widespread and abundant.

A Bull Trout Core Area Assessment

A recovery unit status assessment should consider (1) the status of the core areas it contains, and (2) the interaction between core areas. For a recovery unit to be deemed viable, most core areas should be at least minimally stable (i.e., at a relatively low risk of extirpation), and the spatial arrangement and connectivity between core areas should be preserved such that the entire recovery unit can withstand both environmental and demographic stochasticity. These two considerations are measured in comparison to two thresholds proposed by the Bull Trout Technical team: a stability threshold, and a stronghold threshold.

First, the stability threshold was characterized to capture the minimum conditions that a core area needs to be considered stable. Core area conditions are assessed using the NatureServe methodology, and the stability threshold has a NatureServe score of 2.5; i.e., "vulnerable" as defined by the rank calculator. The demographic values that these minimum conditions represent fall within the range of those identified within the bull trout literature and best available science as those mostly likely to allow a bull trout core area to persist (see below for inputs and support). The persistence of these core areas ensures the minimum necessary representation and redundancy in the recovery unit. Below a NatureServe score of 2.5 (i.e., imperiled or critically imperiled), individual demographic values begin to be eroded to such a point that the probability of persistence of individual core areas significantly declines.

Second, the stronghold threshold was characterized to capture the minimum conditions that some core areas (one per major geographic region within a recovery unit) need to achieve to preserve spatial integrity of the recovery unit and serve as source populations for other connected core areas. Core areas that achieve the stronghold threshold have a NatureServe score of at least 3.5 (i.e., apparently secure). These core areas have a lower risk of extirpation than core areas that achieve the stability threshold, and have the potential to serve as a source for dispersal, recolonization, and support to other core areas in each major geographic region within the recovery unit, thus ensuring representation and resiliency across the RU.

Bull trout core area status assessments in the entire coterminous range were updated in 2012, and current NatureServe scores were calculated for each. Core areas that are generally considered stable by the Service and our partners have current NatureServe scores near 2.5 (or above), and core areas that are considered to be stronger have higher scores closer to (or above) 3.5; hence, there is an intuitive match between core area scores and status (imperiled, vulnerable, and apparently secure).

The Characteristics of Bull Trout Core Areas: An Empirical Assessment

It is possible to understand the types of conditions and combinations of conditions that actually (and currently) characterize core areas with various rank scores. The following is an assessment of what NatureServe rank calculator inputs are associated with the overall NatureServe rank score from existing core area status assessments. We used existing NatureServe rank scores and characterized the conditions that were associated with those conditions.

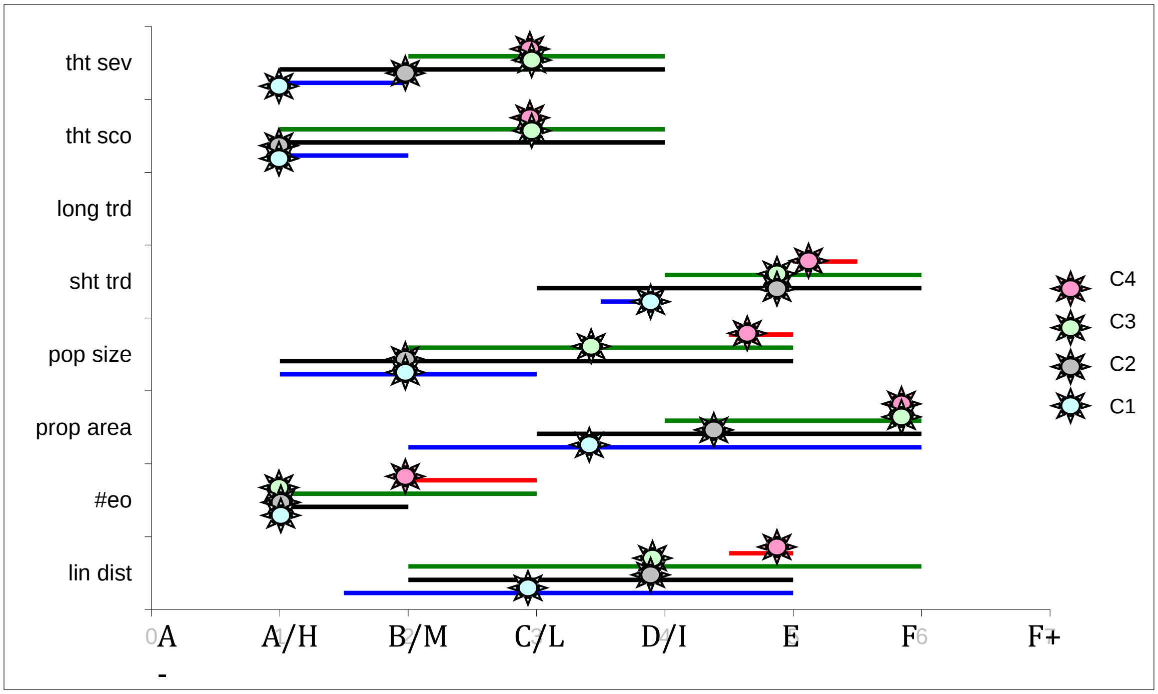
In the range of bull trout, most core areas differ from the hypothetical average core area (described in the following section). For example, most core area short term trends are not rapidly declining (the hypothetical average), they are either moderately declining, stable, or even increasing (i.e., most are better than average). Further, most core areas do not have between 21 and 80 local populations (the hypothetical average); most have between 1-5 or 6-20 (i.e., most are less than average). So, where a core area is deficient in one respect, another attribute might bolster the deficiency and still result in a score that meets a given threshold.

We characterized 109 core area assessments (Table 2). Of these core areas, 32 of 87 had a rank score of 2.51 or greater (C3 and C4 in Figure 1). Of those core areas with rank scores 2.51-3.5 (C3 above), the linear distance of occupancy was never worse than category B, the number of local populations was never worse than category A, the proportion of area in good condition was never worse than category D, the population size was never worse than category B, the short term trend was never worse than category CE, the threat scope was never worse than category high and the threat severity was never worse than category moderate. Only four core areas had a rank score of 3.5 or greater. Thus, the sample size of these core areas was too low to make any significant inference about their characteristics. However, of those core areas with rank scores of 3.5 or greater (C4 above), linear distance of occupancy was never worse than category DE, number of local populations was never worse than category B, proportion of area in good condition was never worse than category F, population size was never worse than category DE, short term trend was never worse than category E, threat scope was never worse than category low and threat severity was never worse than category low. For a given core area rank score category, there tended to be a large range in input values, emphasizing that there are many ways for a core area to achieve a given condition.

Table 2. Median (± Range) of rank calculator input category and associated core area rank score category. Data from actual, 2012 assessments.

| | Core area rank score (number of core areas) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0-1.5 (N=17) | | | 1.51-2.5 (N=60) | | | 2.51-3.5 (N=28) | | | 3.51-4.5 (N=4) | | |
| | Rank calculator input | | | Rank calculator input | | | Rank calculator input | | | Rank calculator input | | |
| | best | med | worst | best | med | worst | Best | med | worst | best | med | worst |
| Lin. Dist. Occ. | E | C | AB | E | D | B | F | D | B | E | E | DE |
| No. loc. pop. | A | A | A | B | A | A | C | A | A | C | B | B |
| Prop. Area | F | CD | AC | F | DE | C | F | F | D | F | F | F |
| Pop. Size | C | B | A | E | B | A | E | CD | B | E | DE | DE |
| Short trend | D | D | CD | F | E | C | F | E | CE | EF | E | E |
| Long trend | - | - | - | - | - | - | - | - | - | - | - | - |
| Threat scope | m | h | h | i | h | h | I | l | h | l | l | l |
| Threat severity | m | h | h | i | m | h | I | l | m | l | l | l |

Figure 1. Median (± Range) of rank calculator input category and associated core area rank score category.  C4 = rank score of 3.51-4.5, C3 = rank score of 2.51-3.5, C2 = rank score of 1.51-2.5, C1 = rank score of 0.0-1.5.




The Characteristics of Core Areas: A Hypothetical Assessment

It is possible to understand the types of conditions, and combinations of conditions, that could characterize core areas with various rank scores.  The following is an assessment of how changes in NatureServe inputs affect the overall NatureServe rank score for a hypothetical core area.  This assessment can be viewed as a basic sensitivity analysis. We calculated the overall NatureServe rank scores for three core area conditions: 1) a core area in poor condition, where all inputs to the rank calculator were set to the lowest or worst bins (Table 3);  2) a core area in average condition, where all inputs to the rank calculator were set to an approximation of average input bins (Table 3); and  3) a core area in good condition, where all inputs to the rank calculator were set to the highest or best bins (Table 3).

Table 3. NatureServe element inputs for poor, average and good core area conditions.

| NatureServe Element | Core Area Condition | | |
|---|---|---|---|
| | Poor | Average | Good |
| Lin. Dist. of Occup. | A (< 4 km) | D (200 – 1000 km) | H (> 200,000 km) |
| No. of Local Pops | A (1-5) | C (21 – 80) | E (> 300) |
| Prop. of Area Good | B (very small, <5%) | D (moderate, 11-20%) | F (excellent, >40%) |
| Pop. Size | A (1 – 50) | D (1000 – 2500) | H (> 1,000,000) |
| Short-Term Trend | A (severe, > 70%) | C (rapid, 30 – 50%) | F (increasing, > 10%) |
| Long-Term Trend | A (hi. decline, > 90%) | C (subs. decl., 50-75%) | F (increase, > 25%) |
| Threat Scope | High (> 60%) | Moderate (20 – 60%) | Insignificant (< 5%) |
| Threat Severity | High (> 100 yr to recovery) | Moderate (50 – 100 yr to recovery) | Insignificant (< 10 yr to recovery) |

Table 4. NatureServe rank scores of hypothetical core areas under poor, average, and good scenarios. For a given core area scenario (e.g. poor), when all rank calculator inputs the same (e.g. poor) the rank score is consistent (e.g. 0.12). Other combinations of inputs for each of the three core area conditions were also calculated. These were achieved by changing one of the inputs to a different condition and leaving all other inputs the same. For example, in the poor core area condition scenario, the rank score was 0.63 if all inputs were set to poor, except for linear distance of occupancy, which was set to average. Similarly, in the good core area condition scenario, the rank score for the core area was 5.16 when all inputs were set to good, except for population size, which was set to average.

| Rank Calculator Categories | Core Area Scenario: Poor | | | Average | | | Good | | |
|---|---|---|---|---|---|---|---|---|---|
| | Poor | Avg | Good | Poor | Avg | Good | Poor | Avg | Good |
| Lin. Dist. of Occup. | 0.12 | 0.63 | 1.31 | 1.92 | 2.43 | 3.12 | 4.30 | 4.82 | 5.50 |
| No. of Local Pops | 0.12 | 0.72 | 1.31 | 1.84 | 2.43 | 3.03 | 4.31 | 4.90 | 5.50 |
| Prop. of Area Good | 0.12 | 0.36 | 0.60 | 2.20 | 2.43 | 2.67 | 5.02 | 5.26 | 5.50 |
| Pop. Size | 0.12 | 0.37 | 0.72 | 2.18 | 2.43 | 2.77 | 4.90 | 5.16 | 5.50 |
| S-T Trend | 0.12 | 0.34 | 0.67 | 2.21 | 2.43 | 2.76 | 4.95 | 5.17 | 5.50 |
| L-T Trend | 0.12 | 0.34 | 0.67 | 2.21 | 2.43 | 2.76 | 4.95 | 5.17 | 5.50 |
| Threat Scope | 0.12 | 0.26 | 0.67 | 2.30 | 2.43 | 2.85 | 5.23 | 5.36 | 5.50 |
| Threat Severity | 0.12 | 0.26 | 0.67 | 2.30 | 2.43 | 2.85 | 5.23 | 5.36 | 5.50 |

Hypothetical core area rank scores ranged from 0.12 to 5.50. The average core area condition resulted in a rank score of 2.43 (Table 4), very close to the proposed 2.5 threshold (stable). The rank score for an average core area was characterized by a core area having a linear distance of occupancy of 200-1000 km, 21-80 local populations, a moderate proportion (11-20%) of area in good condition, a population size of 1000-2500 individuals, short term trend of rapidly declining (30-50%), long term trend of substantial decline (50-75%), and threat scope and severity both moderate. In general, the most obvious way for a core area to achieve a rank score near 2.5 was to have all inputs approximate average conditions. However, some inputs could be poor and, with the appropriate combination of other inputs being average and good, a core area could also achieve a rank score near 2.5. It appeared that, in general, inputs would need to be some combination of average to good for a core area to achieve a rank score of 3.5 or better. However, it was possible for a core area to achieve a rank score of 3.5 with some inputs being poor. If some inputs were poor, a relatively high proportion of good inputs were necessary for a core area to achieve a rank score of 3.5. Overall, the rank scores appeared most sensitive to the number of local populations and the linear distance of occupancy. In summary, there were several ways for a core area to reach both the 2.5 (stable) and 3.5 (stronghold) rank score thresholds. The assessment conducted here represents only a small number of the possible combinations of rank calculator inputs, but this provides a basic understanding of the population and habitat characteristics that core areas will generally have for any given rank score.

<u>The Relationship Between Core Area Thresholds and Bull Trout Biology</u>

Knowledge of bull trout biology can be applied to inform the NatureServe rank score thresholds being used to reflect core area status. In particular, specific examples of the hypothetical evaluation, described above, can inform the identification of rank score thresholds which characterize moderate and low risk of core area extirpation. We conducted such evaluations by using information associated with the biology of bull trout to determine the various inputs to the categories being used in core area status assessments.

As discussed previously, the number of local populations in a bull trout core area can range from one isolated population (simple core area), to many connected populations (complex core area) that function as a metapopulation. The risk of extirpation for a simple core area is largely associated with the dynamics of a single population. In general, small, isolated populations can have an inherently higher risk of extirpation than multiple, well-connected populations (see Hanski and Gilpin 1991). Alternatively, the risk of extirpation for a metapopulation (complex core area) is inversely associated with the number of local populations in that metapopulation (Fagan 2002). For bull trout, approximately 10 local populations within a core area appear to be the minimum necessary for it to function reasonably well as a metapopulation (see Rieman and Dunham 2000; Whitesel et al. 2004). The minimum catchment area to support each of these populations is approximately 400-500 hectares (Rieman et al. 1997). Converting this catchment area to linear stream distance (the variable used in core area status assessments) suggests that a reasonably well functioning population of bull trout would occupy a minimum of 4-200 km of stream. The risk of core area extirpation can also be related to the availability of high quality habitat (see Higdon et al. 2006). To be at moderate or low risk of extirpation, it is reasonable to suggest that at least a substantial proportion of the core area would have good viability and ecological integrity (see Rieman and McIntyre 1993). In addition, to be at moderate or low risk of extirpation, it appears that the threats to bull trout persistence (such as harvest, degraded habitat, introduced species, and climate change) would be low or insignificant (see Staples 2006, Rieman et al. 2007). Each population would require a minimum of approximately 100 spawners to avoid significant demographic and genetic risk (Schultz and Lynch 1997; Rieman and Allendorf 2001; Allendorf and Ryman 2002; also see Whitesel et al. 2004). Growth rate and trend, both long and short term, are also important factors in determining a core area's risk of extirpation (Lande 1993; Fagan 2002). A core area at high risk of extirpation would be characterized by a chronically low population growth rate or a negative trend in abundance whereas a core area at moderate risk of extinction would have a stable trend (Caughley 1994; see McElhany et al. 2000).

Based on the information associated with bull trout biology, we determined the minimum conditions that would combine to reflect a core area at <u>moderate risk of extirpation</u> (stable). Using these conditions, we derived inputs for the NatureServe Rank Calculator. Specifically, we input: linear distance of occupancy (4-200 km), number of local populations (6-20), proportion of area in good condition (11-20%), population size (250-1,000), short term trend (-30 to +10%), long term trend (-50 to +25%), threat scope and severity (low). The rank score that resulted from this input ranged from 2.48-2.87. Thus, a rank score of at least 2.5 appears to be a reasonable estimate of the minimum necessary for a core area to be at a moderate risk of extirpation.

Based on the information associated with bull trout biology, we also determined the minimum conditions that would combine to reflect a core area at low risk of extirpation (stronghold). Using these conditions, we derived inputs for the NatureServe Rank Calculator. Specifically, we input: linear distance of occupancy (40-992 km), number of local populations (21-80), proportion of area in good condition (21-40%), population size (1,000-2,500), short term trend (-10 to +100%), long term trend (-25 to +100%), threat scope and severity (insignificant). The rank score that resulted from this input ranged from 3.37-3.76. Thus, a rank score of at least 3.4 appears to be a reasonable estimate of the minimum necessary for a core area to be at a low risk of extirpation.

We specifically evaluated rank scores that could be associated with moderate or low risk of core area extirpation. The rank scores that resulted from this exercise corresponded well with categories already developed for use with the NatureServe approach (Faber-Langendoen 2009). As such, it appears that the biology of bull trout is consistent with the categorizations developed by NatureServe. Thus, we recommend using the existing rank scores thresholds developed by NatureServe (i.e. 2.51-3.5, 3.51-4.5) and having those reflect the relative risk of extirpation (moderate and low, respectively). In addition, it is important to note that the conditions we used are only one subset of possible inputs that would generate such a rank score. Ultimately, it is the rank score (not the individual inputs) that are recommended for characterizing the risk of core area extirpation.

## Conclusion

NatureServe is a useful tool that can be used to describe the status of core areas across the range of bull trout in a consistent and transparent manner. Hypothetical and empirical analyses suggest that scores between 2.51 and 3.5 correspond well with conditions that characterize relatively stable core areas, and that scores between 3.51 and 5.5 correspond well with conditions that characterize core areas that could serve as strongholds within recovery units. Additionally, these ranges in scores also reflect an intuitive match between the calculated risk status and that perceived by bull trout experts and partners. Core area stability in addition to connected strongholds are likely to result in recovery unit viability. Having core area stability throughout most of a recovery unit (i.e. all complex core areas and half the simple core areas) ensures that the recovery unit can maintain representation and redundancy of bull trout biodiversity. Providing stronghold core areas that are spatially arranged to serve as source populations to other core areas ensures that the recovery unit can maintain representation and resiliency.

## Simple Core Areas

We define a Simple Core Area as a core area that contains one bull trout local population. Simple core areas are almost always small in scope, with a population size that is necessarily restricted by the size of the habitat. Typically, simple cores are ecologically if not physically isolated from other core areas by natural, not anthropogenic factors (e.g., natural barriers, thermal gradients, or large spatial separation from other core areas) that have been operable for thousands of years. Overall, simple core areas contribute less to the viability of a recovery unit than complex core areas, and therefore not all simple core areas need to achieve the stability threshold. If additional local populations are discovered or are colonized, a simple core area would be reclassified as a complex core area.

The following distribution of simple core areas occurs across the six recovery units:

Coastal RU – 2
Klamath RU – 1
Mid-Columbia RU – 3
Upper Snake RU – 3
Columbia Headwaters RU – 20
Saint Mary RU – 3
TOTAL - 32

<u>Rationale for why 50% of extant simple core areas are necessary for a recovery unit to be viable</u>

In order to adequately evaluate this element of the viability rule set, it is important to first understand the geomorphic origins and relative placement of simple core areas in the ecosystems where they occur. In the Columbia Headwaters and Saint Mary recovery units, where most (23/32) of the simple core areas occur, nearly all are adfluvial migratory populations based in lakes, located in the upper headwaters of hydrologic systems that originate on or near the Continental Divide. Similar circumstances occur in Odell Lake in the Coastal Recovery Unit. A majority of simple core areas are in alpine habitat in protected landscapes, such as Glacier National Park or federally designated Wilderness (Fredenberg et al 2007: Meeuwig 2008: USFWS 2010). Typically, the outlet streams from these lakes flow into larger streams which attach to adfluvial migratory bull trout populations located downstream.

Most lakes that form the FMO habitats for simple core areas are relatively small (22-1,724 acres), quite deep (typical max depth >100 feet), and located in glaciated valleys on simple linear 2$^{nd}$ or 3$^{rd}$ order stream systems (both inlet and outlet), whose 1$^{st}$ or 2$^{nd}$ order tributaries typically flow off steep mountainous terrain either too steep or too intermittent to contain perennial fish populations. Even though the lakes are at relatively high elevation, they do absorb sufficient thermal energy to warm surface temperatures to 60-65° F or higher in the summer months. As a consequence, surface outlet streams are frequently much warmer in the summer than adjacent streams flowing from drainages which do not contain lakes, and such streams often exceed bull trout thermal preference. These streams also cool later in the fall due to the upstream heat budget in the lake and are generally not used by bull trout for spawning. As a consequence, lake outlet streams are typically not occupied by bull trout, especially in summer, acting as thermal barriers to further isolate simple core areas, even though adjacent streams may provide important bull trout spawning and rearing habitat.

Bull trout populations in these lakes, which typically spawn in the first kilometer or two of stream upstream of the lake, and rear in either the lake itself or the few kilometers of stream that are accessible, are typically low density and individuals are slow growing due to the biologically sterile systems in which they occur. However, due to the presence of other native forage species (*cyprinid* spp., *catostomid* spp., westslope cutthroat trout, and mountain whitefish) and relatively long lifespan (exceeding 10+ years) common in harsher environments, bull trout in these lakes are still capable of reaching sizes approaching 3.5-4.5 kg. In addition to downstream thermal barriers, natural waterfall barriers occur frequently in these systems and bull trout in these simple core areas are often restricted in migratory movements either upstream, downstream, or both (Fredenberg et al 2007).

In a few cases, particularly in the Coastal, Mid-Columbia, and Upper Snake recovery units, simple core areas do not fit the above description. Rather than an adfluvial life history, bull trout in these simple core areas may be fluvial or resident in nature but are either isolated in small basins upstream of natural barriers (e.g., Little Minam, West Fork Klickitat), or simply have very small and isolated watersheds (e.g. Sheep and Granite Creeks).

Meeuwig et al. (2010) examined the influence of landscape characteristics on genetic differentiation among bull trout populations just described in the Glacier National Park headwaters landscape. They concluded the presence and spatial configuration of barriers between core areas and the tributary distance separating core area populations were important in accounting for the degree of genetic differentiation between bull trout populations. Additionally, bull trout occupying lakes in the same drainage were predicted to be more similar than bull trout in lakes occupying different drainages. Meeuwig et al. (2010) also found genetic differentiation decreased as overall patch size increased. Patch size is often used as a surrogate for habitat carrying capacity or population size, which is related to genetic drift and differentiation (Frankham et al. 2002). Mogen and Kaeding (2005), working in the Saint Mary Recovery Unit on the other side of the Continental Divide, corroborated similar factors that have contributed to the long-term isolation of bull trout in headwater lakes, despite a well-connected network of migratory bull trout in the Saint Mary River system downstream.

Thus, there is strong physical and biological support for the determination that each of these lakes or lake systems is accurately characterized as simple core areas. Because they have persisted, mostly in isolation, ostensibly for thousands of years at relatively low population levels, they somewhat challenge our thinking about minimum viable population size and the need for metapopulation structure in order to persist. We can characterize the existing simple core areas that we observe today, but there are often similar systems in adjacent headwater basins that seem to have adequate habitat attributes to support bull trout in simple core areas, but they do not. Undoubtedly, some of these were colonized and extirpated over geologic history. Based on stochastic events, we would expect a much higher rate of extirpation amongst isolated simple core areas. This higher likelihood of extirpation is acknowledged in the 50% rule we are presenting.

Peripheral populations (i.e., bull trout in simple core areas) are important to the species and may contain important genetic resources (Haak et al. 2010). These core areas functionally resemble individual local populations attached to complex core areas rather than the complex core areas themselves. As such, their importance to the overall landscape distribution and abundance of the species, especially over ecological and evolutionary time, is difficult to quantify. We discuss this in the context of the three R's - *Resiliency, Redundancy*, and *Representation.* As described in the Recovery Strategy:

> "Resiliency involves ensuring that each population is sufficiently large to withstand stochastic events. Redundancy involves ensuring a sufficient number of populations to provide a margin of safety for the species to withstand catastrophic events. Representation involves conserving the breadth of the genetic makeup of the species to conserve its adaptive capabilities."

*Representation*

Representation is a valid concern. Simple core areas are by their very nature subject to genetic drift and founder effects and tend to have low genetic variability within (Meeuwig et al. 2010). However, because of this, they also represent a significant, perhaps even disproportionate amount of the genetic variability between core areas. Phenotypic variability is apparent in some of these populations as well and there may be adaptive traits yet to be determined or described. Nielson et al. (2001) assert that peripheral populations at the edge of a species' range not only can carry unique genetic structure and provide new evolutionary material when compared to populations at the core of a species' range, but the evolutionary future of a species could ultimately rely on its peripheral populations. Specifically regarding bull trout conservation, Epifanio et al. (2003) assert the highest priority, as well as the greatest investment, should be directed to depleted, unique, and isolated populations as the most irreplaceable elements of biological diversity. They considered not only genetic irreplacibility, but also ecological irreplacibility. However, we are not proposing to require that stability in all peripheral populations (core areas) is necessary to achieve adequate representation under bull trout recovery. Given the small scope and relative isolation of these core areas, it's unlikely that those genetic traits will be easily shared with larger downstream metapopulations in the short term. Their capability for genetic transfer is very limited under current, natural circumstances. However, over ecological or evolutionary time frames, many independently evolved isolated core areas are likely beneficial to the recovery unit. Independently, these simple sore areas generally have relatively low genetic variability and probability of persistence.

*Redundancy*

Because the types of ecosystems that these simple core areas naturally occur in are functionally similar (often hydrologically simple linear glacial-carved systems with a lake and a short inlet stream) and relatively common in headwater locations, there is often a naturally high level of redundancy over a relatively small landscape scale. Indeed, it is striking how similar many of these ecosystems are in appearance and how their attributes are replicated. However, there are sometimes more than subtle differences amongst them in terms of the extent and quality of spawning and rearing habitat (Fredenberg et al. 2007; Meeuwig 2008) and the fish species complexes while always simple, are sometimes highly variable (Meeuwig 2008). These attributes probably contribute to the likelihood of persistence for some over others. The presence/absence of bull trout within some very similar systems often appears to be a matter of happenstance due to random natural barriers. Regardless, the level of existing redundancy may be protected or even expanded, even if some existing simple core areas are extirpated.

*Resiliency*

By their very nature, simple core areas are not resilient. Their small size, low population levels, and spatial isolation render them naturally vulnerable to extirpation due to stochastic events. As we have pointed out, once extirpated most are not likely (in some case even not possible) to be naturally refounded. Doubtless, many simple core areas have already been extirpated through geologic history. In most cases, there is nothing that can be done to increase the core area size or population level of bull trout in these core areas. They are naturally vulnerable.

Conclusion

The practical effect of this element of the rule set is that a minimum of 17/32 (53%) of simple core areas across the landscape would need to meet the 2.5 NatureServe threshold (1/2 Coastal; 2/3 Mid-Columbia, Upper Snake, and Saint Mary; 10/20 Columbia Headwaters) in order to fully satisfy the criteria. The recovery plan and recovery criteria are not advocating for the elimination of half (or any) of the simple core areas. However, with this 50% standard we are acknowledging that some simple core areas have been in the past and others in the future will likely be extirpated. Ideally, under properly functioning conditions, whiel some simple core areas may become extirpated, recolonization would also lead to the formation of new simple core areas. The viability rule set is advocating maintaining a representative proportion of the extant simple core areas, or populations.

An additional point is that recovery actions in simple core areas are more achievable as the scope and costs are less daunting and the habitat is typically relatively secure. In the type of habitats where simple core areas exist, establishment of "new" simple core areas in vacant habitats (likely through translocation or transplant) or reestablishment of previously extirpated simple core areas is likely to be considered in the foreseeable future. Under appropriate conditions, we may be more likely to conduct these types of experimental recovery efforts than would be logical for complex core areas.

## Complex Core Areas

We define a Complex Core Area as a core area that contains multiple interacting bull trout local populations. Complex core areas contribute significantly to the viability of a recovery unit and therefore all of them need to achieve the stability threshold.

The following distribution of complex core areas occurs across the six recovery units:

Coastal RU – 18

Klamath RU – 2
Mid-Columbia RU – 22
Upper Snake RU – 19
Columbia Headwaters RU – 15
Saint Mary RU – 1
TOTAL – 77

Scientific Rationale for why 100% of extant complex core areas should achieve the stability threshold:

All complex core areas (those with more than one local population) that currently exist (as of 2012), must meet or exceed the stability threshold measured by a score of at least 2.5 in the NatureServe conservation status assessment tool.

*Exception: In cases where two or more current core areas (originally delineated as an artifact of artificial separation) are consolidated into a single core area in the future due to restored connectivity, only the "new" core area would need to meet the stability threshold.

Achieving stability within all currently extant complex core areas is most likely to provide a high probability for recovery unit viability and persistence. The basis for this concept is that the historical recovery unit was viable. Therefore, the more a recovery unit resembles its historical structure (i.e., reference template), the greater confidence we have that it is and will continue to be viable (see McElhany et al. 2000). A key emphasis of recovery unit viability should be on the stability of complex core areas, since their larger geographic size and multiple local populations make them inherently more likely to persist than simple core areas (Rieman and McIntyre 1993, 1995), and accordingly have greater influence on recovery unit viability (for contrast see section above, Simple Core Areas). In addition, complex core areas make up over 99% of the current spatial distribution of bull trout on the landscape (USFWS 2005). Equally, the continued loss of extant complex core areas inherently erodes the likelihood of preserving overall recovery unit viability. Consequently, the objective we are striving for with this element of the viability rule set is to conserve an approximation of the historical population structure, the best predictor of what is necessary to be viable.

A long standing general principle of conservation biology is "save all the pieces" when there is uncertainty how a system precisely works, especially in the future. This also seems particularly relevant for conservation of bull trout core areas which often function as independent demographic units (i.e., metapopulations) within the larger recovery units. Each core area, but especially those that are defined as complex, contributes to the diverse array of complex life histories and genetic variability exhibited by bull trout across their range (Ardren et al. 2011). The complex life histories exhibited by salmonids are a reflection of the diversity of habitats they live in (Rieman and Dunham 2000). To conserve bull trout, it has been suggested that as a bare minimum, as many bull trout groups as possible representing their likely historical variability, and within those groups all their migratory life histories and relationships, must be fully conserved to be successful and representative (Haas and McPhail 2001). Rieman and Dunham (2000) emphasize that the interaction between spatial and temporal habitat heterogeneity and life history diversity is central to the concept of risk spreading in population biology: the idea that naturally diverse populations may have more stable dynamics in the face of environmental changes. Obtaining stability in all complex core areas preserves the opportunity and options to attain strongholds within each of a recovery units Major Geographic Regions, allows for neighboring core areas to benefit from potential source populations in the event of local extinctions, conserves a broad array of options among all core areas to contribute to recovery under uncertain environmental changes, and prevents the viability of recovery units from being susceptible to a single catastrophic event. There are many examples of where even large populations of char such as bull trout can become vulnerable if present conditions change (Dunham et al. 2008). Rahel et al. (2008) state that managing species of conservation concern is likely to become even more challenging due to the interaction of climate change and invasive species. We acknowledge there is already loss of historical core areas (USFWS 2005), but are not requiring their reestablishment in order to achieve recovery unit viability even though their loss in combination with demographic declines and threats in other (extant) core areas led to the species' listing as threatened under the ESA. The problem will be especially acute for the many aquatic species of conservation concern that have specific habitat requirements and limited ability to migrate to new habitats.

This concept has been similarly applied in salmon recovery planning. NOAA recommends actions should be taken such that all extant populations within Evolutionarily Significant Units (ESUs) retain the potential to achieve viable status until a final recovery plan can establish ESU-level criteria (McElhany et al. 2000). Gustafson et al. (2007) state it is apparent that to preserve biodiversity at multiple scales in wild Pacific salmon, both the local population (used in a manner roughly equivalent to bull trout core areas) and its habitat must become the basic unit of conservation. In fact, NOAA's salmon recovery planning efforts have established short-term objectives at the ESU level where all independent populations (roughly equivalent to bull trout core areas) must improve in status relative to their current state. The uncertainty typically surrounds how much improvement within each population is required (Tear et al. 2005).

NOAA lists seven elements under its ESU Viability Guidelines (McElhany et al. 2000), which are easily applicable to bull trout recovery units (approximate ESU equivalents) and core areas (population equivalents):

1. ESUs should contain multiple populations.
2. Some populations in an ESU should be geographically widespread.
3. Some populations should be geographically close to each other.
4. Populations should not all share common catastrophic risks.
5. Populations that display diverse life-histories and phenotypes should be maintained.
6. Some populations should exceed Viable Salmonid Population guidelines.
7. Evaluations of ESU status should take into account uncertainty about ESU-level processes.

Options for achieving bull trout recovery unit viability under these guidelines are most easily preserved by striving for the stability threshold in all complex core areas. However, we acknowledge and anticipate that there may be the future loss of complex core areas as a result of stochastic events and future environmental changes, especially those currently with poor demographic conditions and under significant threat. Although the specific losses in population and habitat diversity for the species are unlikely to be reclaimed, loss of recovery unit viability may be partially or largely compensated or mitigated through recolonizations or reintroductions into other historically occupied areas/watersheds (and conceivably into areas/watersheds that were historically unoccupied) if appropriate donor populations are available. In instances where there is good connectivity between several closely related core areas within the same Major Geographic Region, the ability to achieve the stability threshold in all of the closely related core would likely be dependent on each other. This may be especially true when any of the closely related core areas are in a condition well above the stability threshold and may serve as sources for the other core areas.

*Representation*

This rule set element in large part ensures adequate "representation" is captured within recovery units across the range of bull trout. Not only does it ensure the likelihood sufficient representative populations within the core of the range will be conserved, but adequate peripheral populations will be conserved as well. Compared to simple core areas, complex core areas are more likely to naturally persist and to maintain greater potential for adaptability due to their population structure, abundance, and distribution compared to simple core areas. We believe this aspect of our recovery approach for bull trout still sufficiently contributes to the three conservation goals identified by Meffe (1986) for endangered fishes: maintenance of viable populations in the short term (= avoidance of extinction), maintenance of the capacity of fishes to adapt to changing environments, and maintenance of the capacity for continued speciation.

Under bull trout recovery, we also believe this rule set element largely contributes to the ESA need to, "…provide a means whereby, the ecosystems upon which endangered species and threatened species depend may be conserved."

*Redundancy*

This rule set element in large part ensures adequate "redundancy" is captured across the range of bull trout. Redundancy is necessary to reduce to an acceptable level the risk of losing representative examples of bull trout core areas or populations (Tear 2005). This rule set element helps ensure redundancy of bull trout life history forms, genetic representation, regional distributions, and ecological settings likely necessary to achieve bull trout recovery. Epifanio et al. (2003) also believe multiple strong self-sufficient populations with common genetic and phenotypic characteristics would warrant protection concurrent with those unique irreplaceable populations (see Representation), but with limited investment under stable conditions.

*Resiliency*

Although this rule set element does not specifically address resiliency, indirectly it preserves the opportunity and option for many complex core areas to reach a state that will provide that role under bull trout recovery. Any complex core area that remains at a vulnerable status (i.e., below the stability threshold) will not be able to contribute to resiliency for the species.

## **Stronghold Core Areas**

We define a Stronghold Core Area as a complex core area where bull trout populations are strong and diverse and the habitat has high intrinsic potential to support bull trout. Stronghold core areas must meet or exceed the stronghold threshold measured those that have a rank score of at least 3.5 from the Nature Serve conservation status assessment tool. Stronghold core areas meet biological criteria for abundance, productivity, habitat quality, or other biological attributes important to sustaining viable populations of bull trout throughout a geographic region (2011 Pacific Salmon Stronghold Conservation Act). Important characteristics of bull trout strongholds include intact and well-connected habitat (providing both internal and external connectivity relative to the core area), presence of migratory populations, presence of the native fish fauna, resiliency to perturbations, and local populations that retain the genetic and phenotypic diversity of the species. Stronghold core areas can act as source populations in Major Geographic Regions that contain multiple core areas and are important for refounding extirpated populations. They also act as the primary reserve to maintain genetic representation within a Major Geographic Region.

Scientific Rationale supporting the need for strongholds within Major Geographic Regions:

Core areas in Major Geographic Regions share similar genetic, geographic (hydrographic), and/or habitat characteristics. These Major Geographic Regions are groups of core areas that are isolated from one another over a longer period of time than local populations but they retain some degree of connectivity greater than between recovery units. The ultimate purpose of a stronghold is to ensure that a Major Geographic Region is robust enough to provide resilience from a catastrophic loss of one or more core areas. In the context of bull trout, a metapopulation is analogous to a complex core area. Extinction risk is inherently greater in a smaller metapopulation than that of a larger, well connected metapopulation. Essentially, the greater amount of habitat, the higher the probability of persistence over time (Hanski 1998). Consistent with metapopulation theory, Rieman and McIntyre (1995) demonstrated that patch size was directly related to persistence of bull trout. Large patches occupied by bull trout may serve as important refugia and sources of recolonization into unoccupied habitat (Dunham and Rieman 1999). From a source-sink dynamics perspective, a large, less isolated complex core area with habitat of good ecological integrity may contribute to persistence of smaller core areas (Dunham and Rieman 1999; Rich et al. 2003). The need and importance of strongholds is also identified under the seven elements (i.e., elements 5 and 6) of NOAA's ESU Viability Guidelines (McElhany et al. 2000).

In instances where there is good connectivity between several closely related core areas within the same Major Geographic Region, one core area may help another achieve the stronghold threshold. Although not completely duplicative in function, we believe several well connected, closely related core areas with a status near the stronghold threshold, can contribute many of the conservation elements provided by an individual core area meeting that threshold.

*Representation*

This rule set element helps ensure adequate “representation” is captured within recovery units across the range of bull trout. Based on the principles of basic conservation biology, one core area with long-term viability within each major geographic region has the potential to serve as a source for dispersal, recolonization, and demographic support of other core areas in that region as necessary to support sufficient representation across the recovery unit.

*Resiliency*

This rule set element in large part ensures adequate “resiliency” is captured within recovery units across the range of bull trout. A stronghold core area is likely to be a large habitat patch capable of supporting many local populations. Therefore, having a stronghold core area is likely to provide the highest probability of persistence within a Major Geographic Region with multiple core areas. A stronghold core area is important to ensure the principles of resiliency by maintaining a large area of high-quality habitat as well as representing diverse genetic and life history aspects of bull trout populations (Tear et al. 2005). Stronghold core areas are likely to be sufficiently large to achieve the three criteria for habitat resilience that Bisson et al. (2009) identify for Pacific salmon management: 1) the capacity to recover from disturbance without intervention, 2) a full range of habitats to support multiple life histories, and 3) ecological connectivity. We believe these criteria would similarly apply to bull trout habitat. These stronghold core areas are especially important to the resiliency of bull trout under anticipated future environmental variability and changes.

Achieving a stronghold core area may be challenging in various recovery units and some Major Geographic Regions. The Upper Snake is a recovery unit that may pose some challenges. In the Upper Snake, the following major geographic regions exist: Jarbidge core area, Little Lost core area, Malheur core area, Payette core area, and the Weiser core area. The Little Lost is naturally isolated as the basin is a hydrologic sink; the remaining core areas are isolated due to anthropogenic influences and threats. The Jarbidge, Little Lost, and Weiser only contain one complex core area while the Malheur and Payette contain two and four, respectively. The Payette core area is close to attaining a stability threshold and may attain a stronghold threshold in the future. Despite these challenges, it is likely that recovery unit viability requires each geographic region to contain a stronghold core area, Thus, the Service will continue to support recovery actions that aid in stability and help viable populations persist.

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