# A Demographic Monitoring Strategy for Bull Trout Core Areas in Northeastern Oregon and Portions of Southeastern Washington


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in Northeastern Oregon and Portions of Southeastern Washington

## Introduction

The bull trout recovery plan (USFWS 2015) calls for the use of a threats assessment tool for evaluating the threats to the species in recovery units for 5-year status reviews and potential delisting. However, to some extent those threats evaluations and status assessments will be dependent on demographic information related to characteristics of a "recovered" recovery unit: representation (occupancy and life histories); redundancy (populations distributed across the recovery unit); and resilience (migratory life histories and improvement of "at risk" core areas). As stated in the recovery plan:

> "One demonstration of effective threat management is demographically stable bull trout populations as measured at the core area scale. Therefore, demographic data, as well as other empirical data on the magnitude and trends in bull trout population counts or indices; current or historical spatial distribution, connectivity, and extent of populations, will be useful and help inform the effectiveness of primary threat management where such information is available. Because such information is not available in all core areas across the species' range, each RUIP will identify additional monitoring and evaluation needs." (p. 136)

Other recovery plan objectives relevant to demography include:

- "Bull trout will be geographically widespread across representative habitats and demographically stable;
- The genetic diversity and diverse life history forms of bull trout will be generally conserved…"

## Scope

Considerable monitoring and demographic information is available for the Coastal and Klamath recovery units in Oregon, whereas monitoring of bull trout in northeastern Oregon has been less extensive and consistent. In August 2017 the U.S Fish and Wildlife Service (USFWS) Oregon State Office and Philip Howell through Meridian Environmental, Inc. entered into a cooperative agreement that provided three months of support to develop a monitoring strategy in collaboration with the local bull trout working groups of federal, state, tribal, and other agencies for core areas in northeastern Oregon and portions of southeastern Washington where the core areas overlap state boundaries.

Given the constraints of the amount of time and resources available to complete this strategy, it was not feasible to develop detailed, specific sampling designs, methods, and resources (e.g., personnel, funding) needed for implementation. That will require further collaboration with the working groups and, in some cases, consideration of the results from initial implementation of the strategy. Like bull trout conservation, monitoring will be a continuing, evolving process.

While development of this monitoring strategy is based in part on recommendations from the bull trout recovery plan, implementation of the strategy is not a requirement of the recovery plan. The USFWS fully supports implementation of this strategy but acknowledges that implementation is at the discretion of local fish and land management agencies and is dependent on availability of funding and personnel.

This monitoring plan covers the following recovery units and core areas: Mid-Columbia recovery unit (Walla Walla, Lookingglass/Wenaha, Umatilla, North Fork John Day, Middle Fork John Day, Upper Main Stem John Day, Upper Grande Ronde, Little Minam, Wallowa/Minam, Imnaha, Powder, and Pine Creek core areas) and Upper Snake recovery unit (Upper Malheur and North Fork Malheur core areas) (Appendix figure 1).

**Methods and Products**

1. Assemble information for the core areas on past and current monitoring methods and data and potential future sources of demographic data (e.g., weirs, traps, monitoring efforts for other species).
2. Review monitoring methodologies.
3. Develop draft monitoring recommendations for each of the core areas.
4. Distribute draft monitoring recommendations to the federal, state, and tribal agencies for review and comment.
5. Revise and finalize monitoring recommendations.

**General Guidelines**

The following characteristics of monitoring were applied:

- Systematic

  Monitoring should follow a logical and scientifically sound approach to describe the demographic attributes for the populations of interest.

- Generally consistent

  The methods used should be generally consistent from year to year to insure that measurements over time are comparable. At the same time we recognize that as monitoring is conducted, we will learn how to better implement those methods; and they may be modified accordingly. Also, as new methodologies develop (e.g., eDNA), monitoring methods may change as well.

- Appropriate for the populations and settings

  While the methods for individual populations should be generally consistent, different methods may be used for populations with different characteristics, threats, and habitats. For example, different techniques may be more appropriate for migratory vs. resident populations and allopatric bull trout populations vs. mixed bull and brook trout populations. More frequent monitoring may be needed for depressed populations facing a number of severe threats than for large, stable populations in secure habitats.

- Reasonably rigorous

  This monitoring strategy is designed to increase our understanding of the demographic aspects of population status and help inform related management decisions. It was not designed for research projects, project evaluation, or statistical testing of specific hypotheses. Some of the data may be more qualitative or quasi-quantitative but still informative.

- Relatively simple to design, implement, analyze, and interpret

- Realistic given available personnel and funding

  Most of the monitoring proposed will be conducted by the management agencies with existing management personnel, expertise, and funding. In many cases, available personnel and budgets have declined and may continue to do so, which may result in a need to seek additional funding.

- Coordinated

  Given the limitations of personnel and funding, monitoring needs to be coordinated among the management agencies involved.

- Minimally invasive

  Since many populations in this region are depressed, monitoring methods should be designed to minimize stress, injury, or mortality of bull trout and other species.

**Population Units**

At the heart of the Endangered Species Act is conserving biological diversity, especially for species, like bull trout, whose distribution has already substantially declined. Or as stated by Aldo Leopold (1953), "…To keep every cog and wheel is the first precaution of intelligent tinkering." However, keeping all of the parts requires knowing to some degree what all of the parts are.

Genetic analyses (e.g., Spruell et al. 2003; Ardren et al. 2011) indicate that the genetic diversity of bull trout is primarily found between populations rather than within populations. In other words, bull trout populations are very different from each other, whereas individuals within populations are very similar. Although connectivity is important, particularly for maintaining migratory life histories, the highly and finely structured nature of bull trout populations suggests that there can be little-to-no interbreeding among local populations and, consequently, little demographic support among populations even though connectivity may make that possible. Core areas can be collections of essentially demographically discrete local populations, particularly as populations have become more fragmented and migratory life histories have declined (e.g., the Powder core area). This has important implications concerning how we approach conserving diversity, assessing the status of the species, and monitoring. For example, monitoring a small subset of habitats or populations may not be truly "representative" of the diversity of a core area. A reduction of bull trout diversity is not simply a reflection of the loss of core areas but also the loss of populations within a core area. Monitoring needs to include status measures of local populations, not just core areas, to determine the extent to which the diversity of the species is being conserved. Thus, identification of local populations is critical to any monitoring effort.

For a number of analyses, including the range-wide climate vulnerability assessment for bull trout (Dunham 2014) and the range-wide bull trout eDNA project (https://www.fs.fed.us/rm/boise/AWAE/projects/BullTrout_eDNA.html) local populations are assumed to be represented by patches or contiguous reaches of suitable spawning and rearing habitat generally consisting of cold water (Dunham et al. 2002). While this may generally be true, especially considering the fragmented nature of many of the populations in northeastern Oregon, and useful for broadscale analyses, genetic and demographic data suggests there are exceptions. For example, both the vulnerability assessment and climate shield patch delineation identify upper Mill Creek (Walla Walla core area) as a single patch (Figure 1).

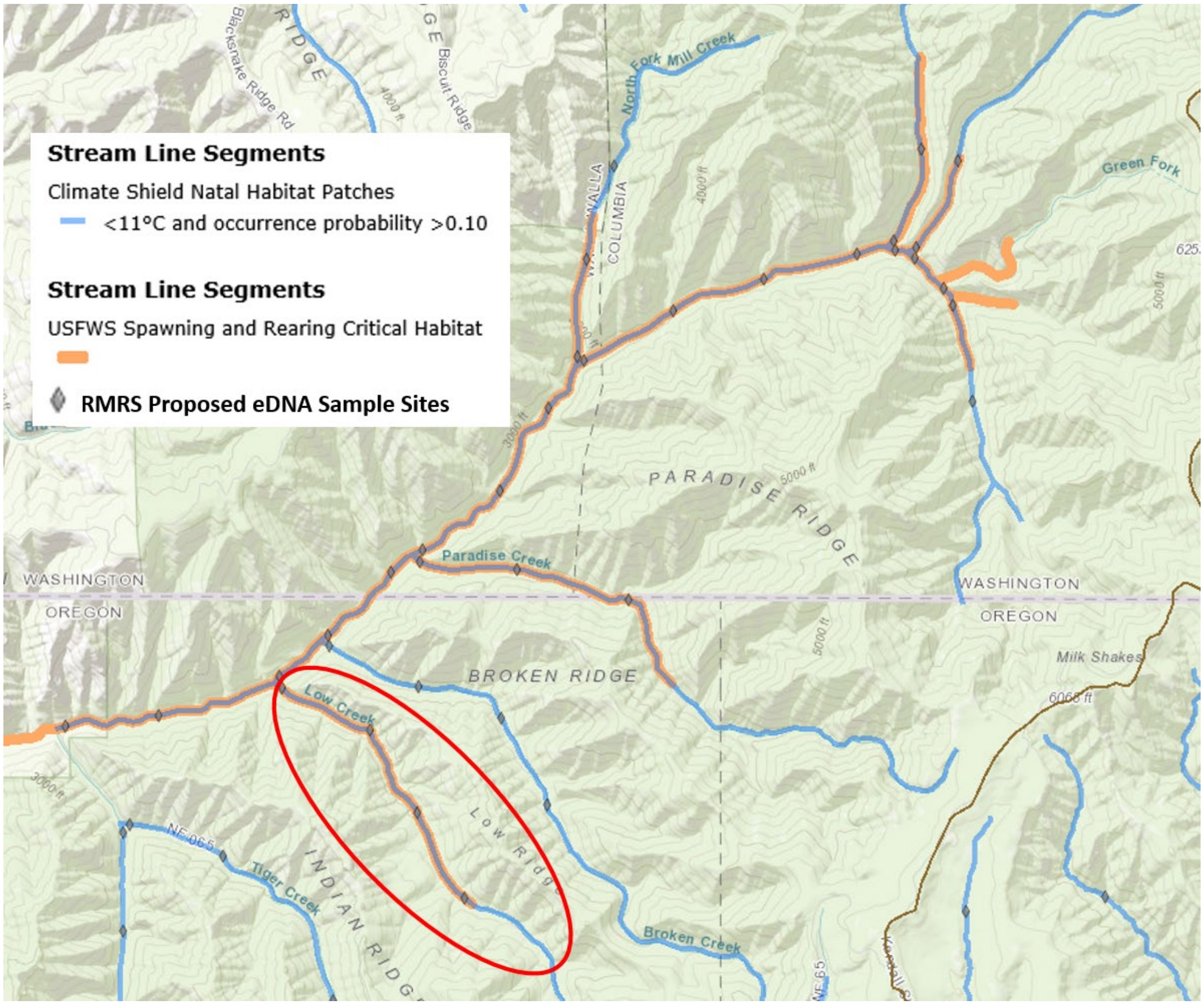



Figure 1. The Mill Creek patch, including Low Creek. (https://usfs.maps.arcgis.com/apps/webappviewer/index.html?id=6d5597b2755c4c00a35613b7a1849760).

However, genetic data indicate that the population in Low Creek, a tributary of Mill Creek, is as much or more genetically distinct from the migratory population in upper Mill Creek as the Mill Creek population is from other core areas as distant as the Wenaha (Grande Ronde) (Table 1). There are no physical barriers separating Low Creek from Mill Creek. Furthermore, the Low Creek population consists entirely of small, resident forms, whereas the Mill Creek population is mostly large, migratory forms. Abundance data also indicate the two populations have very different trends in abundance (Figure 2). Since 1998 the Mill Creek population has substantially declined, whereas the Low Creek population has remained stable. Consequently, pooling demographic data, such as abundance, life history, size, and fecundity, of independent populations, like Low Creek and Mill Creek, could be misleading and complicate interpretation. There are similar data showing high differentiation between closely adjacent populations in Big Sheep Creek and Lick Creek in the Imnaha core area (Figure 3 and Table 2). $F_{st}$ between Big

Sheep and Lick creeks was significantly greater than differences between the more distant Imnaha population and the North Fork Asotin and South Fork Wenaha populations.

Table 1. Pair-wise $F_{st}$ values of bull trout populations in Mill Creek and other core areas in the region (P. Howell, unpublished data). The lower the value the more closely related.

| | Low | Mill |
|---|---|---|
| Mill | **0.12** | 0.00 |
| South Fork Walla Walla | 0.13 | **0.07** |
| Touchet | 0.15 | **0.10** |
| Tucannon | 0.16 | **0.10** |
| South Fork Wenaha | 0.19 | **0.12** |

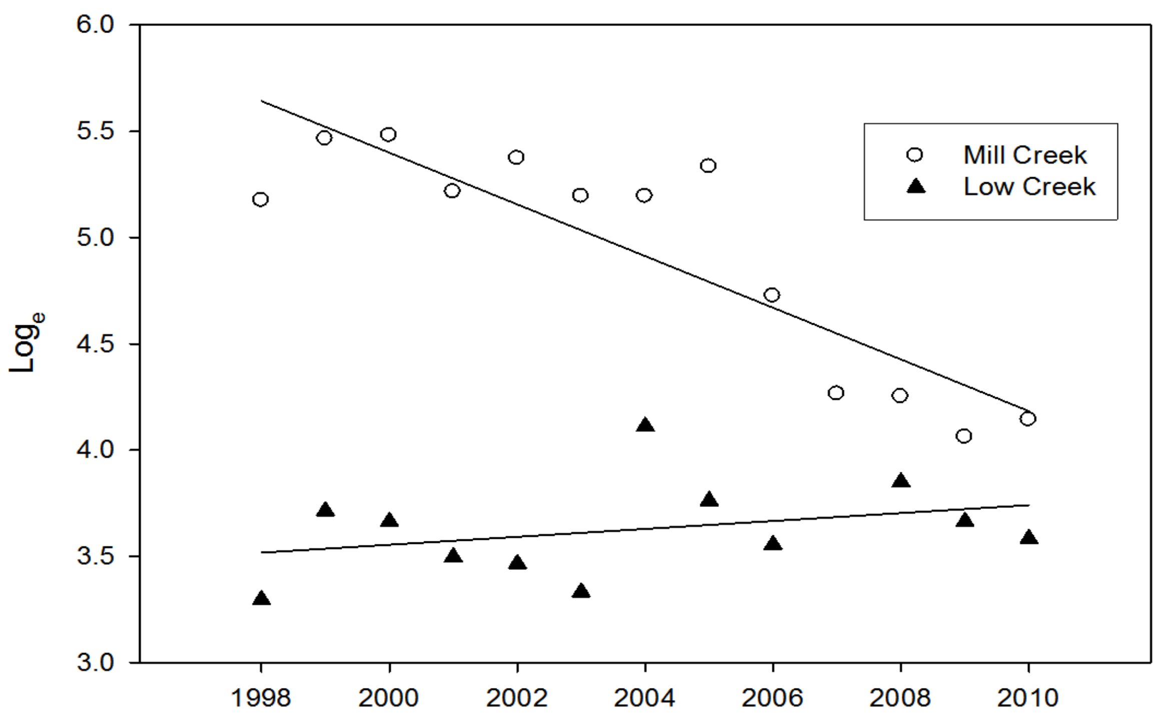



Figure 2. Linear regressions of $\log_e$ estimates of adults in Mill Creek and $\log_e$ redd counts in Low Creek. Mill adults ($r^2$=0.76, $P$= <0.001) Low redds ($r^2$=0.11, $P$= 0.30) (Howell and Sankovich 2012; P. Howell, unpublished data).

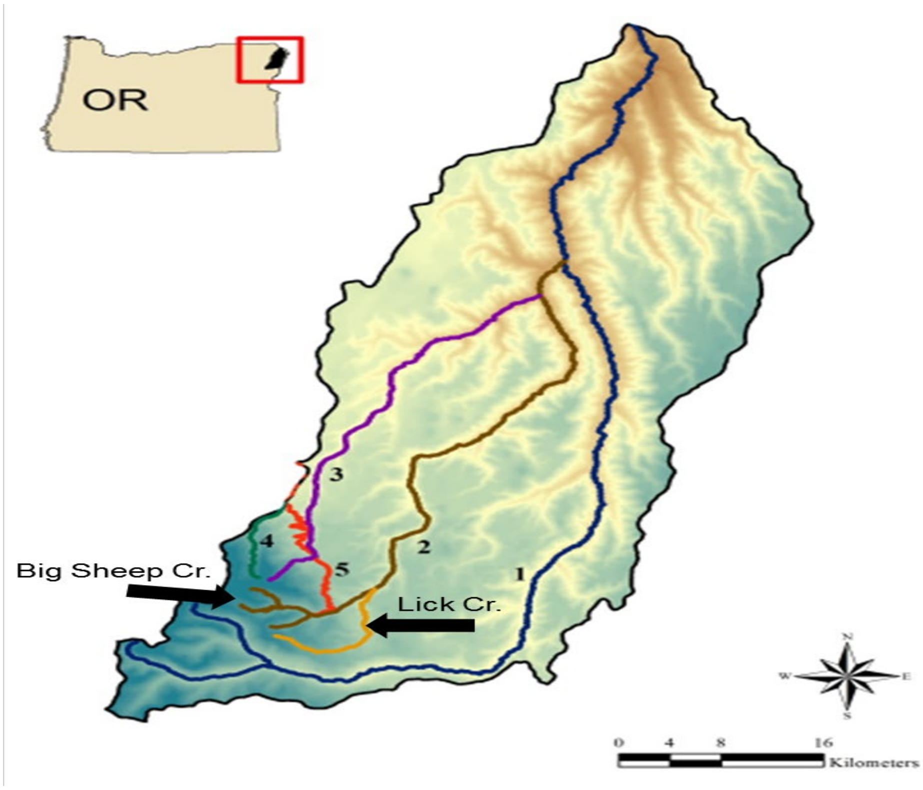



Figure 3. Map showing locations of Big Sheep Creek and Lick Creek (modified from Hudson et al. 2017).

Table 2. Estimates of genetic variation (pairwise $F_{ST}$) among selected bull trout populations in the upper Grande Ronde, Wallowa/Minam, Imnaha, and Asotin Creek core areas (DeHaan et al. 2015).

| | NF Asotin | Lostine | SF Wenaha | NF Catherine | Big Sheep | Lick | McCully | Imnaha |
|---|---|---|---|---|---|---|---|---|
| Lostine | 0.170 | | | | | | | |
| SF Wenaha | 0.071 | 0.152 | | | | | | |
| NF Catherine | 0.166 | 0.199 | 0.138 | | | | | |
| Big Sheep | 0.168 | 0.244 | 0.140 | 0.229 | | | | |
| Lick | 0.097 | 0.159 | 0.092 | 0.135 | 0.113 | | | |
| McCully | 0.107 | 0.180 | 0.093 | 0.153 | 0.128 | 0.083 | | |
| Imnaha | 0.105 | 0.154 | 0.074 | 0.173 | 0.137 | 0.086 | 0.104 | |
| Wallowa | 0.165 | 0.222 | 0.134 | 0.240 | 0.102 | 0.132 | 0.157 | 0.127 |

**Demographic Attributes and Methods**

The following table identifies potential monitoring attributes and methods. Attributes are listed in priority and sequence from coarse to fine scale and in order of increasing intensity of effort and data requirements. Existing sources of data for the core areas are in Appendix tables 1-5.

| Attribute (in priority) | Possible Methods |
|---|---|
| 1. Presence/absence/patch occupancy | eDNA<br>Electrofishing<br>Snorkeling |
| 2. Longitudinal distribution | |
| a. Spawning/rearing/"resident" | Redd counts<br>Electrofishing<br>Snorkeling<br>eDNA |
| b. Migratory | Traps<br>Tagging |
| 3. Life histories | See Distribution and Abundance |
| 4. Abundance (by life history type) | Redd counts<br>Traps<br>Electrofishing<br>Snorkeling<br>Mark-recapture |
| 5. Brook trout<br>(presence, longitudinal distribution, relative abundance, hybridization) | eDNA<br>Electrofishing<br>Snorkeling |
| 6. Genetics (structure, gene flow, abundance/Ne/b, bottlenecks, hybridization) | Electrofishing<br>Traps |
| 7. Vital rates (e.g., survival, productivity) | Mark-recapture |

Presence or absence of bull trout within patches in the core area is the most basic monitoring information. Previously, this was usually done primarily by either electrofishing or snorkeling. Recently eDNA sampling has emerged as an attractive technique due to its simplicity, detection sensitivity, and cost for initially determining presence/absence. However, follow-up sampling with electrofishing or snorkeling is still recommended with positive eDNA results to confirm the presence of a population rather than occurrence of one or a few individuals from another population. As part of assembling existing monitoring information for the core areas, we combined geo-referenced fish sampling data from the Oregon Department of Fish and Wildlife (ODFW) aquatic inventory project (Charlie Stein, ODFW unpublished data), U.S. Forest Service (USFS) stream surveys (Pierre Dawson, USFS, unpublished data) , eDNA sampling data (https://www.fs.fed.us/rm/boise/AWAE/projects/BullTrout_eDNA.html); Archuleta and Ratliff, undated; R. Wilkison, Idaho Power, unpublished data; J. Zakrajsek, Confederated Tribes of the Umatilla Reservation (CTUIR), unpublished data; GeoSense 2018), and patches with ≥50% probability of bull trout occurrence from the Bull Trout Vulnerability Assessment (Dunham 2014) (Appendix figures 2-15). Note: USFS data indicate if the species occurs anywhere within the entire survey reach and are not specific to a sample site. Working groups are encouraged to use the ArcMap files or a larger map to provide adequate detail for additional analysis and project planning.

Once bull trout presence in a patch has been established, spawning and juvenile rearing habitat and migratory distribution should be determined. This can frequently be done in conjunction with identifying the life history forms (resident, migratory) present. Systematic sampling of juvenile rearing/resident adult distribution using electrofishing or snorkeling can be simple to design and implement and provide relative abundance estimates of juveniles and resident adults (≥150 mm; Howell and Sankovich 2012) as well as longitudinal distribution (e.g., Howell 2018; Wilkison and Trainer 2017). A similar systematic design (1 sample unit/stream km) is also used for the Range-Wide Bull Trout eDNA Project (https://www.fs.fed.us/rm/boise/AWAE/projects/BullTrout_eDNA.html). Spatially continuous snorkel surveys or "riverscape" designs (e.g., Brenkman et al. 2012) are also an alternative, particularly for larger streams, where electrofishing is not practical or efficient to determine distribution, relative abundance, and size class (juvenile, subadult, adult).

Since brook trout can be a serious threat to bull trout populations, distribution and relative abundance of brook trout and hybridization should also be monitored. Genetic analysis provides definitive identification of hybrids and pure char species; however, visual identification from phenotypic characteristics has also been shown to be very accurate (DeHaan et al. 2009) and is less expensive. In a more recent study (Wilkison and Trainer 2017) only 1% of bull trout, brook trout and hybrids (*N*=438) were misidentified from phenotypic characteristics. Systematic sampling using electrofishing is well suited for determining distribution, relative abundance, and hybridization of char in systems with mixed bull trout and brook trout, particularly where resident forms are prevalent (e.g., Howell 2018; Wilkison and Trainer 2017). Day snorkeling is less efficient (Peterson et al. 2002) and is likely to be less reliable for identification since the fish are not examined in hand but may be preferable when larger fluvial adults are present, which are more likely to be injured by electrofishing (Reynolds and Kolz 1988).

Redd counts are the most widely used measure of bull trout abundance. They can provide precise estimates of both population size and trend in adult abundance, particularly for fluvial populations (Howell and Sankovich 2012). Redd counts have several advantages over other abundance measurement techniques. They directly reflect the number of adult breeders and, consequently, don't require data or assumptions concerning survival and distribution of juveniles and subadults. Besides adult abundance, redd surveys can identify the spawning and indirectly the juvenile distribution of the populations. They are minimally invasive since they do not involve the capture and handling of fish. They can also be less expensive than trapping and mark-recapture. Since the size of a redd is directly related to the size/life history form of the adult that created it, redd size can also be used to estimate the proportions of small resident forms vs. large, fluvial/adfluvial forms in the population (Figure 4).

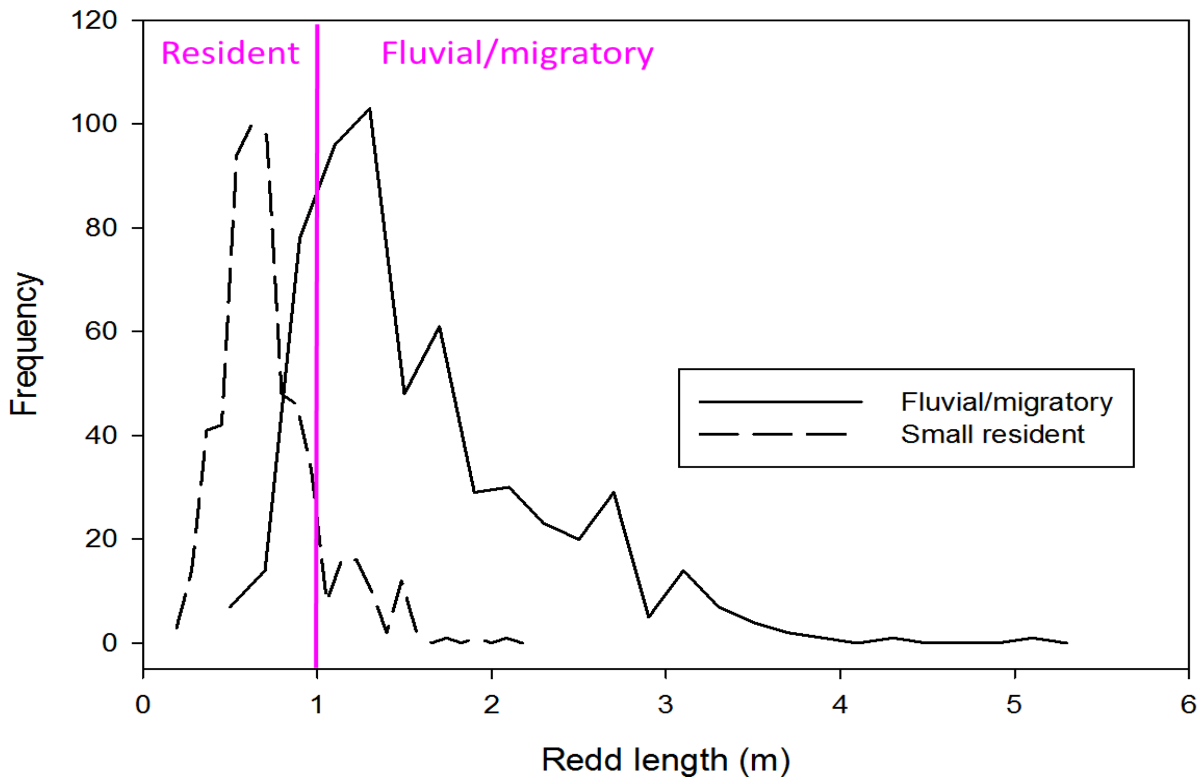



Figure 4. Redd lengths of resident [Low Creek (Walla Walla), Little Minam R., (*N* = 589)] and fluvial [Mill Creek (Walla Walla), (*N* = 573)] bull trout (data from Howell and Sankovich 2012). Redd lengths of <1 m accounted for 85% of the resident redds and lengths of ≥1 m accounted for 88% of the fluvial redds. Redds lengths of ≥1 m for resident redds may have included multiple, adjacent redds classified as a single redd. The Spearman correlation between redd length and area was 0.96 (*P*=0.0000002).

While redd counts can be used for both resident and migratory populations, redd counts of small resident forms are less accurate and potentially less precise than for larger, migratory forms. For example, mean counts of fluvial redds for experienced surveyors matched the "true" counts in Mill Creek, while counts of resident redds in Low Creek were consistently underestimated by ≥45% by both experienced and inexperienced surveyors (Figure 5). Thus, redd counts for resident forms are more of an index of abundance than an absolute estimate of total abundance.

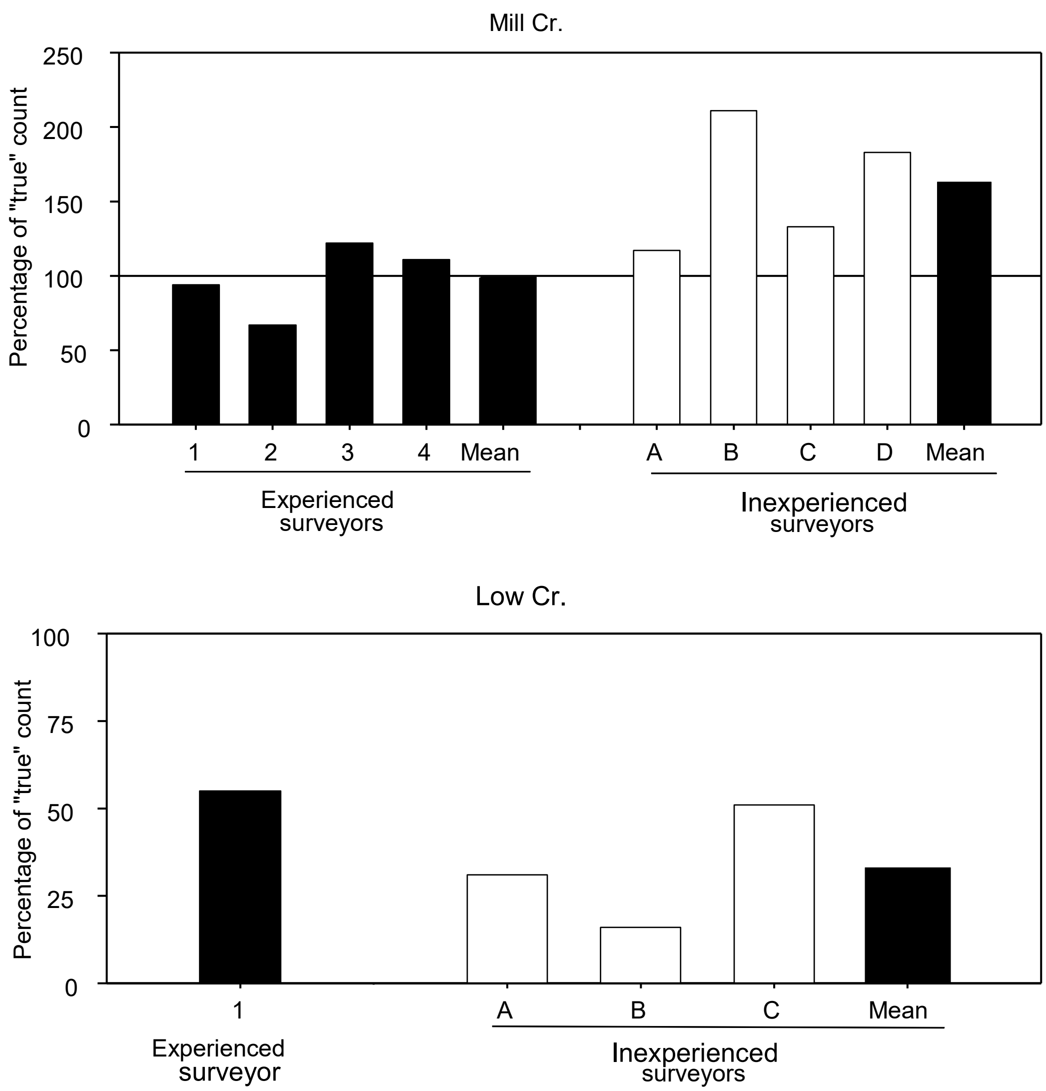



Figure 5. Mean redd counts expressed as a percentage of the best estimate of the true number of redds for experienced and inexperienced surveyors in test reaches containing large, fluvial redds in Mill Creek and small, resident redds in Low Creek (Howell and Sankovich 2012).

These data also emphasize the importance of using experienced surveyors to count redds. Counts by inexperienced surveyors were both more variable and consistently biased. Consequently, experienced and inexperienced surveyors should be paired to provide more reliable estimates of redd numbers and to help train the inexperienced surveyors.

Redd counts are problematic in sympatric bull and brook trout populations, particularly for resident forms where the adults and redds of both species are similar in size. The bull trout spawning period is generally well defined. Although brook trout are suspected to spawn later than bull trout, there have been no studies of the timing of brook trout spawning in northeastern Oregon or other adjacent core areas. Thus, it is unclear how much overlap there is in spawning timing (Figure 6). The occurrence of hybrids in mixed populations demonstrates there is at least some.

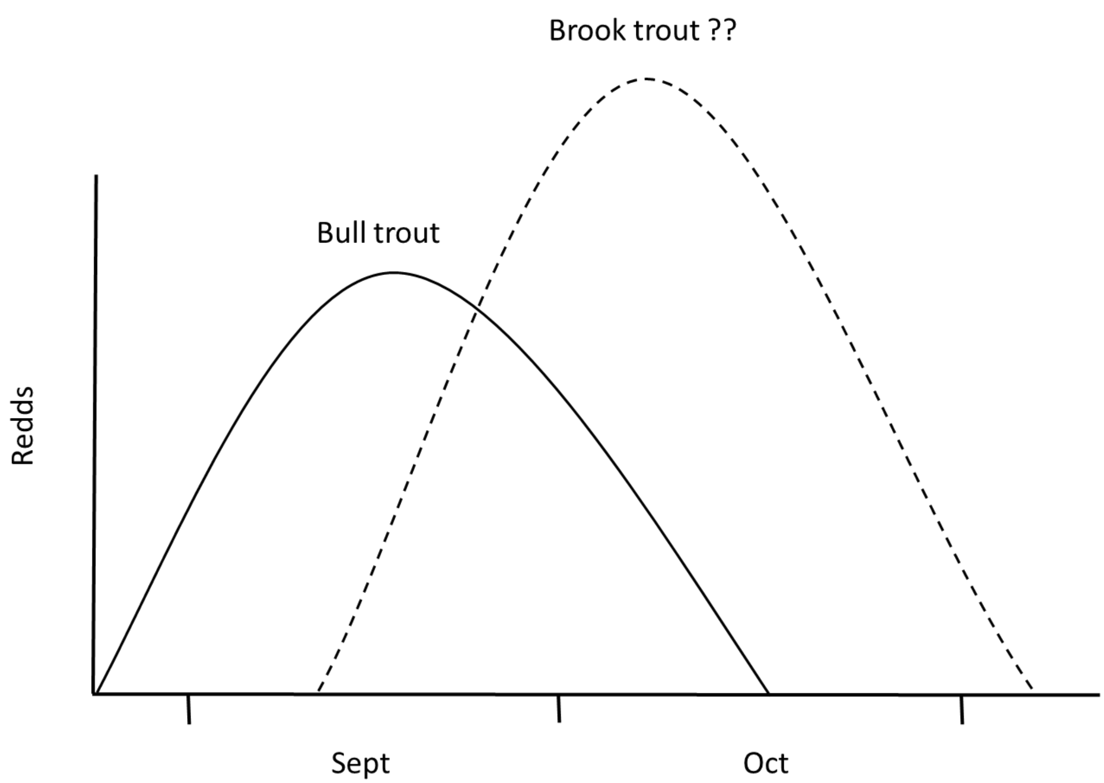



Figure 6. Hypothetical overlap in the spawning periods of bull and brook trout.

Abundance is usually measured either as total population size or as an "index" or relative measure of the total population size and as a trend over time. Trends can be difficult to determine statistically with a high degree of certainty. As Gerrodette (1993) states, "It is usually surprising and sometimes depressing to find out how low power is, how high the detectable rate of change is, and how many years are required to detect a change." In Mill Creek (Walla Walla), for example, data on the variation in redd counts indicate that over a 10-year period it requires more than a doubling or more than an 50% reduction in the population size for it to be a statistically significant increase or decline using typical statistical criteria ($\alpha = 0.05$, power = 0.8, and a two-tailed test) (Howell and Sankovich 2012). For some populations, this is due to inherent fluctuations and variation in abundance (Figure 7).

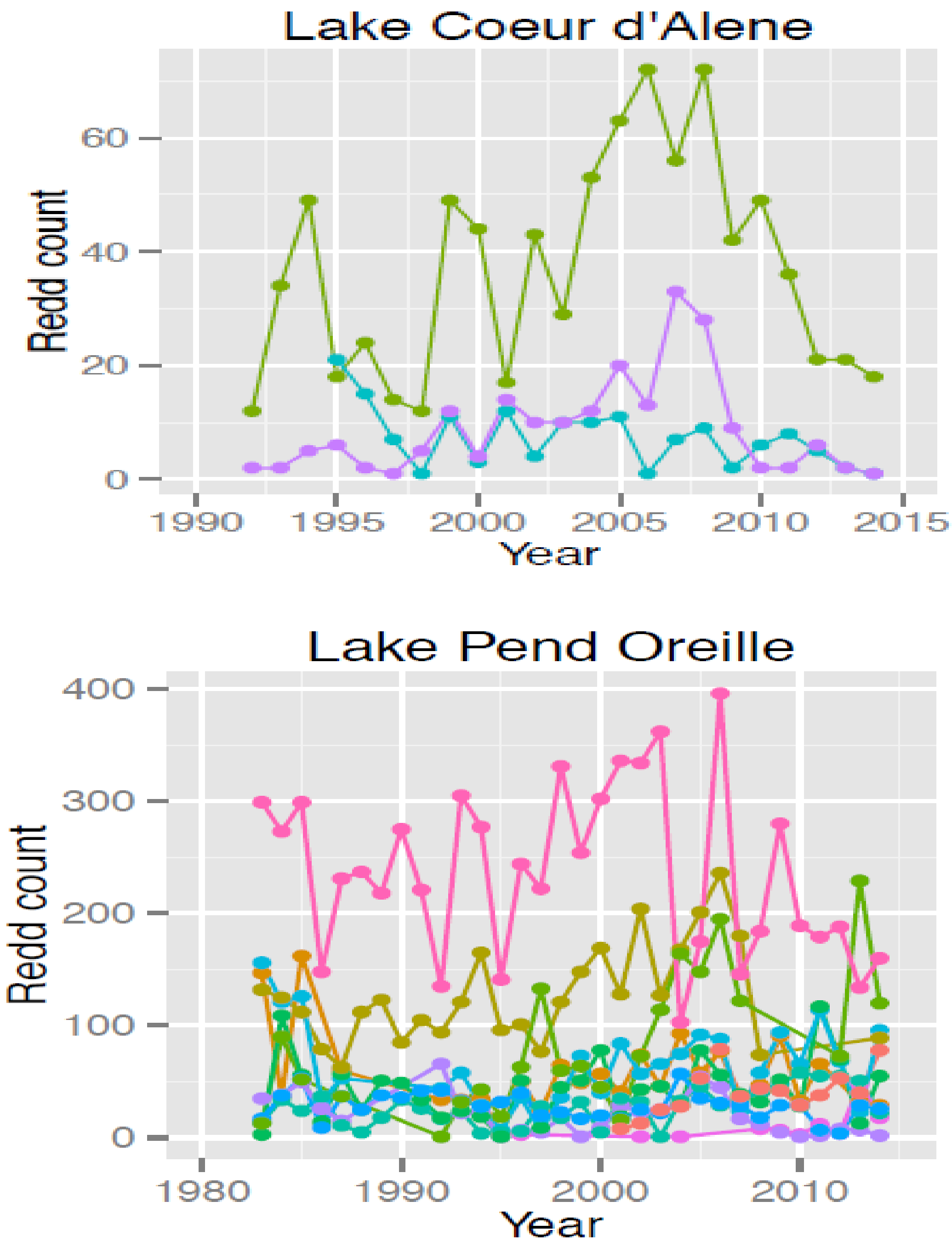



Figure 7. Redd counts of bull trout populations in the Lake Coeur d'Alene and Lake Pend Oreille core areas (Kovach et al. 2018).

It is apparent from these data that the abundance of these populations varied considerably, sometimes increasing and sometimes declining, and, consequently, trends varied as well depending on the time period. However, despite the long-term non-linearity of some abundance data and related statistical uncertainties, abundance data over time can still be informative. For example, these data demonstrate the large fluctuations and resilience in those populations in some cases and also identify relative abundance classes (e.g., low <20 redds, moderate 20-99 redds, high 101-400 redds) relevant to status.

It's also useful to evaluate abundance of a population in the context of the size and productive capacity of its habitat. For example, at face value the Low Creek (Walla Walla) population appears to be depressed compared to the Little Minam River population (Figure 8). However, both populations may be near their production potential since both occur in relatively pristine habitat with little-to-no threats.  The differences in abundance levels are likely due to the much more limited habitat in Low Creek (Low Creek=3.4 km of stream vs. L. Minam=17.8 km, Figure 1 and Appendix figure 14) and perhaps productivity.

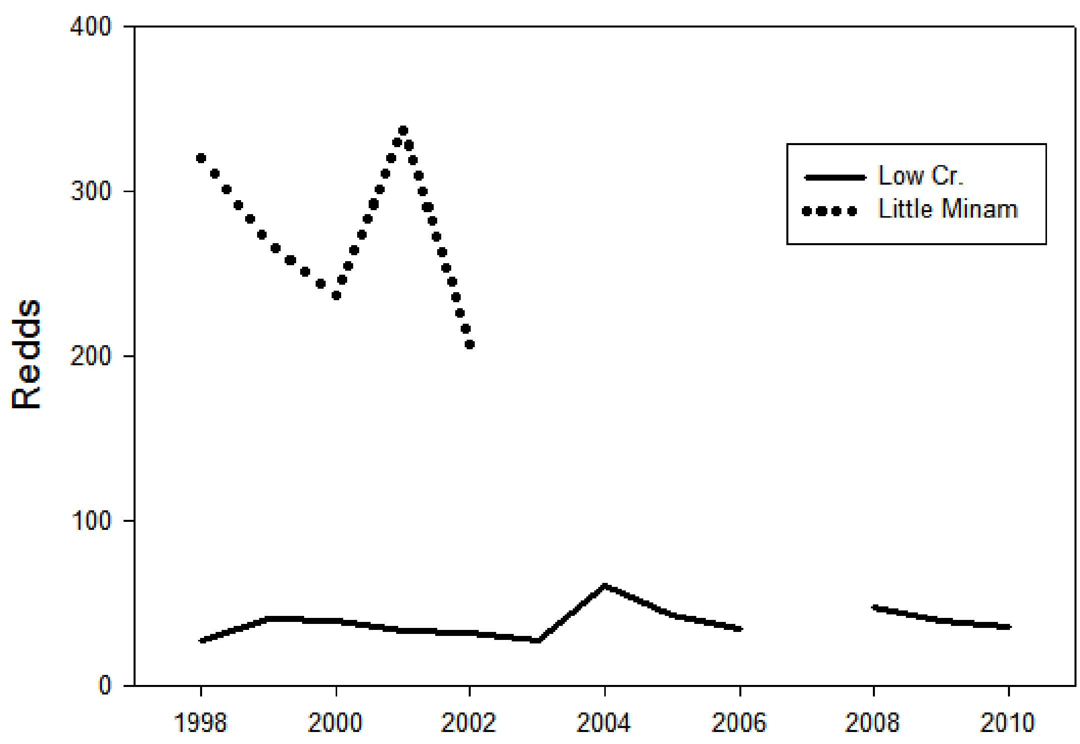



Figure 8. Redd counts in Low Creek (Walla Walla) and the Little Minam River (P. Howell, unpublished data).

Despite the advantages of spawning surveys, the precision and accuracy of redd counts depends on some critical assumptions and aspects of the sampling design. The basic assumption is that the streams surveyed and the number of redds in the survey reaches are representative of the total number of redds of the entire population. This assumption can be met by either surveying the entire spawning population (census), a formal sampling design (e.g., systematic), or by determining the relationship between the redd count in the survey reaches to the total spawning distribution. This is a frequent problem when “index” reaches are initially established without first determining what the full spawning distribution is.  This can be done with a census of all redds (i.e., multiple surveys of the total spawning distribution) or by an extensive “peak” count of the total spawning distribution conducted shortly after most of the fish have spawned.

Other sampling considerations include the number and timing of the surveys within a season and the annual frequency of the surveys. Ideally, the number and timing of the surveys should be determined so that the surveys capture all of the redds created. For example, in most systems in northeastern Oregon spawning primarily occurs during September until mid-October. Since about 90% of the fluvial redds and 75% of the resident redds remain detectable for three weeks (data from Howell and Sankovich 2012), two surveys conducted mid-way and at the end of the six-week spawning period should account for a high proportion of the redds. Since statistical trend detection depends to some degree on the number of years of data, annual redd counts are optimal, but that may not be possible given the number of populations, extent of the survey reaches, and limitations on the number of surveyors for some core areas. It is also likely to be more informative to collect redd count data more rigorously but less frequently rather than more frequently but with greater inconsistency in methods and uncertainty as to whether it reflects the population.

eDNA is promising in terms of estimating abundance (e.g., see Baldigo et al. (2017) for brook trout), but its application for bull trout abundance has not yet been developed.

Genetic analyses can be used to estimate effective population size ($N_e$) and effective number of breeders ($N_b$). However, it requires large sample sizes, which makes it difficult and a fish-handling concern when sampling small populations, where effective population size and number of breeders is of greatest concern. Consequently, at this time it is impractical compared to other methods for routine monitoring. Genetic analyses of population structure remains a very valuable tool for identifying population units for monitoring as discussed above.

Monitoring survival and productivity using mark-recapture and PIT-tagging can be very useful in identifying limiting factors and critical life stages influencing the status and demography of the populations. These more intensive, detailed demographic data (e.g., age structure, age at maturity, fecundity, sex ratio, spawning frequency) can also be used in viability analyses.

However, this type of sampling and analyses is not feasible through most routine monitoring programs.

**Analysis of Existing Data and Monitoring Recommendations**

*Powder River Core Area*

Upper and North Fork Powder River Populations

Distribution and relative abundance of bull trout, brook trout, and hybrids were sampled in 1996 and 2013-2015 (Figures 9 and 10). Populations appear to be resident forms; however, there is potential for some individuals from tributaries above Phillips Lake, most likely from Silver Creek, to migrate to Phillips Lake, as evidenced by subadult bull trout collected there during gill-net sampling in the past and recent positive detections of bull trout with eDNA sampling at the mouth of the Powder River upstream of Phillips Lake (BOR 2016, 2017; unpublished data). A 350 mm bull trout was also collected in Silver Creek in 2015 (P. Howell, unpublished data). The current distribution of bull trout populations is restricted to a few km at the upper fish-bearing limits of the watersheds, similar to the 1990s (Howell 2018). For most populations there is also overlap with brook trout and hybridization.

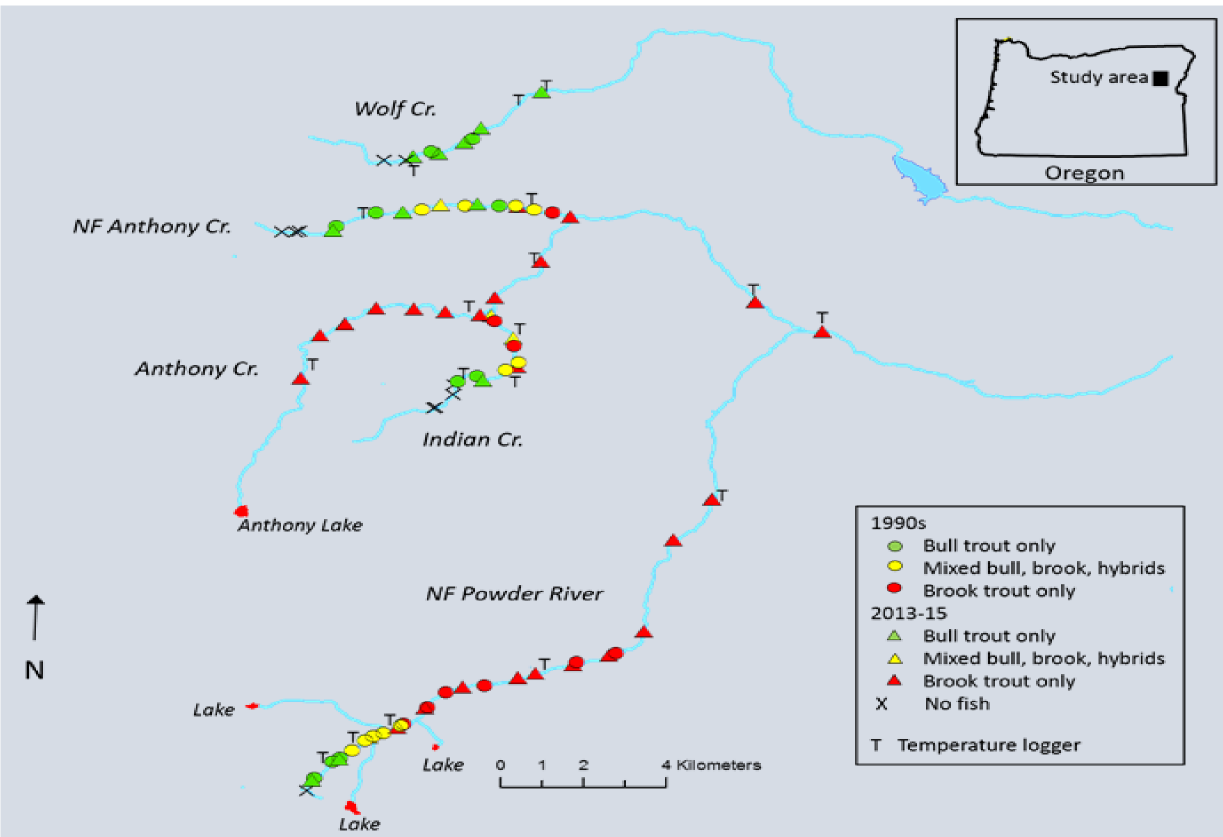



Figure 9. Bull trout and brook trout distribution in Wolf and Anthony creeks and the North Fork Powder River from sample sites in the 1990s and 2013-2015. Lakes identified in red contain naturalized brook trout populations (Howell 2018).

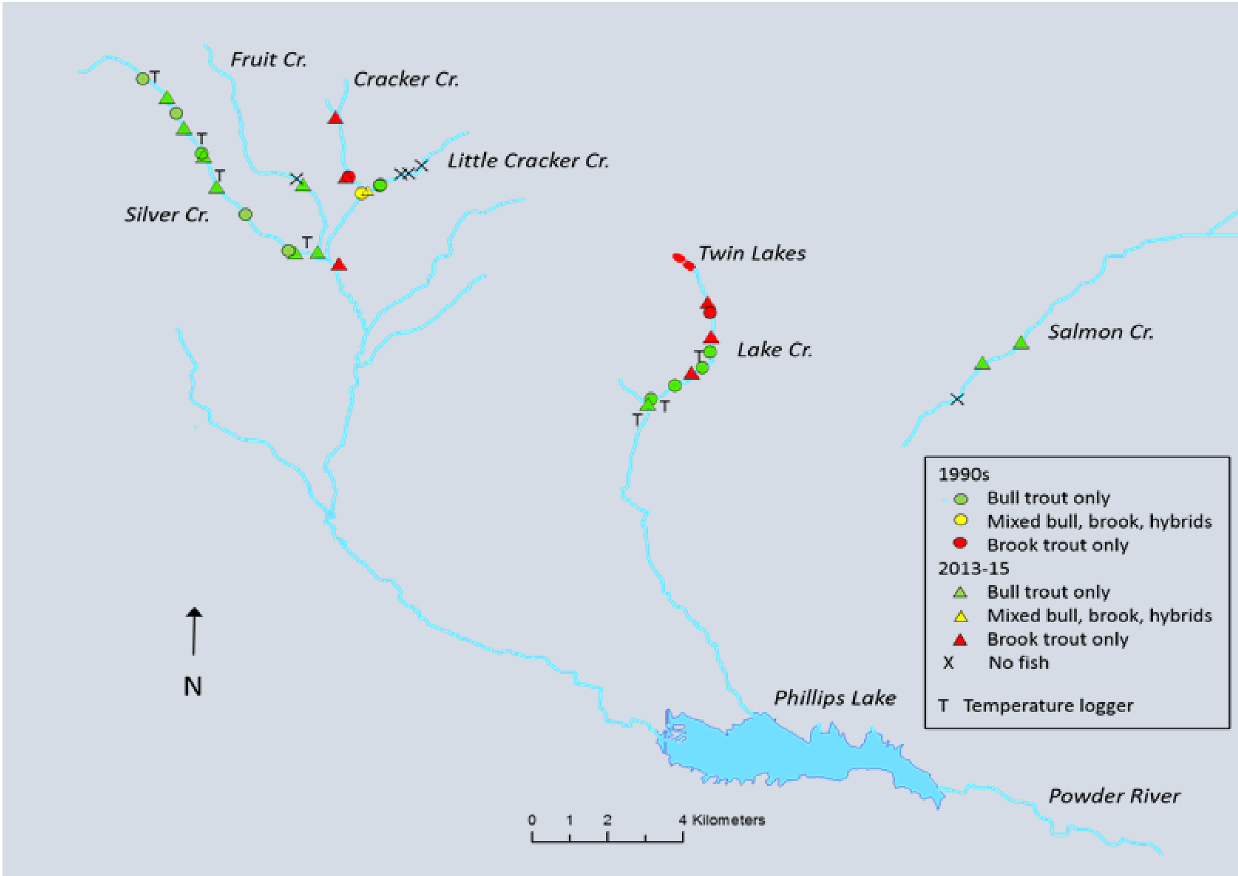



Figure 10. Bull trout and brook trout distribution in Salmon Creek and tributaries of the upper Powder River from sample sites in the 1990s and 2013-2015. Lakes identified in red contain naturalized brook trout populations (Howell 2018).

Proposed Upper and North Fork Powder Monitoring

- Continue monitoring of bull trout and brook trout distribution, relative abundance, and hybridization at 5-10 year intervals with systematic electrofishing. This could be done on a rotating basis among watersheds.

- Sample for migratory subadult bull trout in the Powder River above Phillips Lake with a downstream trap during late spring-early summer, PIT-tag subadults, and operate a PIT-tag antenna array in the river above the reservoir to detect returning tagged adults and evaluate subadult-to-adult survival in the reservoir

- Sample Pine Creek and Big Muddy Creek using eDNA and/or electrofishing to determine the presence and distribution of bull trout. Evaluate other potential patches (Appendix figure 2) (e.g., Sutton, Beaver creeks) for occupancy.

Eagle Creek

Bull trout occurred historically in Eagle Creek as recently as the 1980s (Buchanan et al. 1997). However, none have been documented during sampling since then (Appendix figure 2). Brook trout are prevalent in upper reaches. Eagle Creek was extensively sampled for presence/absence of bull and brook trout using eDNA in 2017; however, analysis of those samples is not complete (R. Wilkison, pers. com.). Limited eDNA sampling in 2014 was negative for bull trout presence (Archuleta and Ratliff, undated).

Proposed Eagle Creek Monitoring

- Follow-up any positive eDNA detections with sampling of distribution, relative abundance, and hybridization of bull trout and brook trout with systematic electrofishing

- Evaluate other potential patches (Appendix figure 2) for occupancy

*Pine Creek Core Area*

Distribution, abundance, and hybridization were sampled by Idaho Power Corporation (IPC) in 2013-2016 using electrofishing (Figures 11 and 12) (Wilkison and Trainer 2017), similar to the sampling done in the upper Powder. Upstream and downstream traps were also operated during 2012-2015 to sample migratory forms. However, only two bull trout were captured, indicating the current Pine Creek populations are primarily resident forms (Wilkison and Trainer 2017). Populations are restricted to upper reaches, in some cases with overlap with brook trout and hybrids occur, similar to the Powder core area populations.

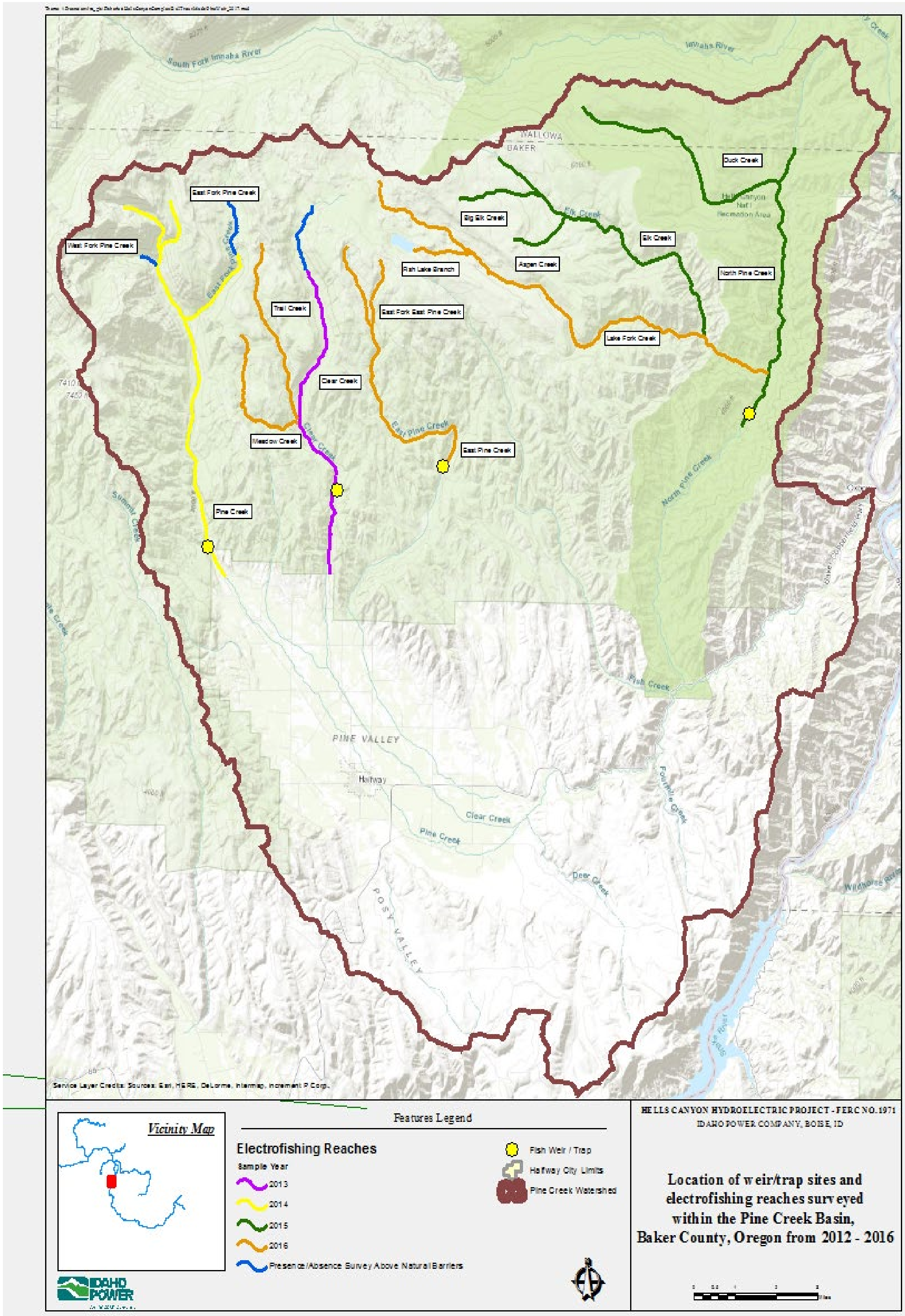



Figure 11. Electrofishing reaches and weir/trap sites in the Pine Creek core area (Wilkison and Trainer 2017).

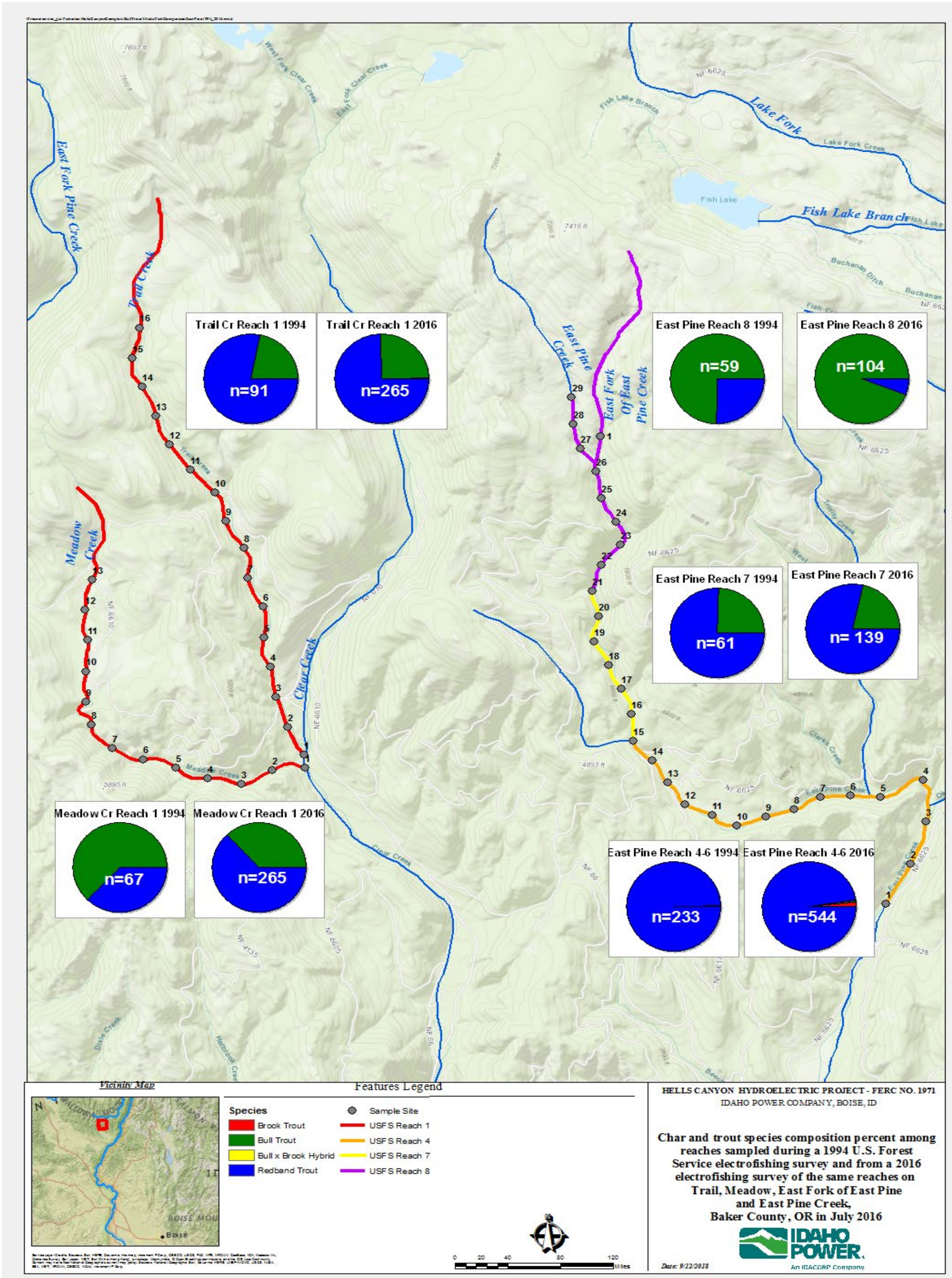



Figure 12. Char and trout species composition percent among reaches sampled during a 1994 U.S. Forest Service electrofishing survey and from a 2016 electrofishing survey of the same reaches on Trail, Meadow, East Fork of East Pine and East Pine Creek, 2016 (Wilkison and Trainer 2017).

Spawning surveys in the Pine Creek system have been done since 1998 (Figure 13). Most counts in the survey reaches, except for East Fork Pine Creek, have been less than 20 redds. Surveys were discontinued in Clear Creek in 2012 and in Aspen and Meadow creeks in 2015. The presence of brook trout in Pine and East Fork Pine creeks complicates redd counts of those populations. IPC plans to continue sampling distribution and abundance with electrofishing and PIT-tagging and operating detection arrays to evaluate possible reestablishment of migratory forms under the terms of their FERC relicensing (R. Wilkison, IPC, pers. com.). The following recommendations are based on those plans, the nature of the Pine Creek populations (i.e., small populations of resident forms in some cases mixed with brook trout), and the limited added value of redd counts there.

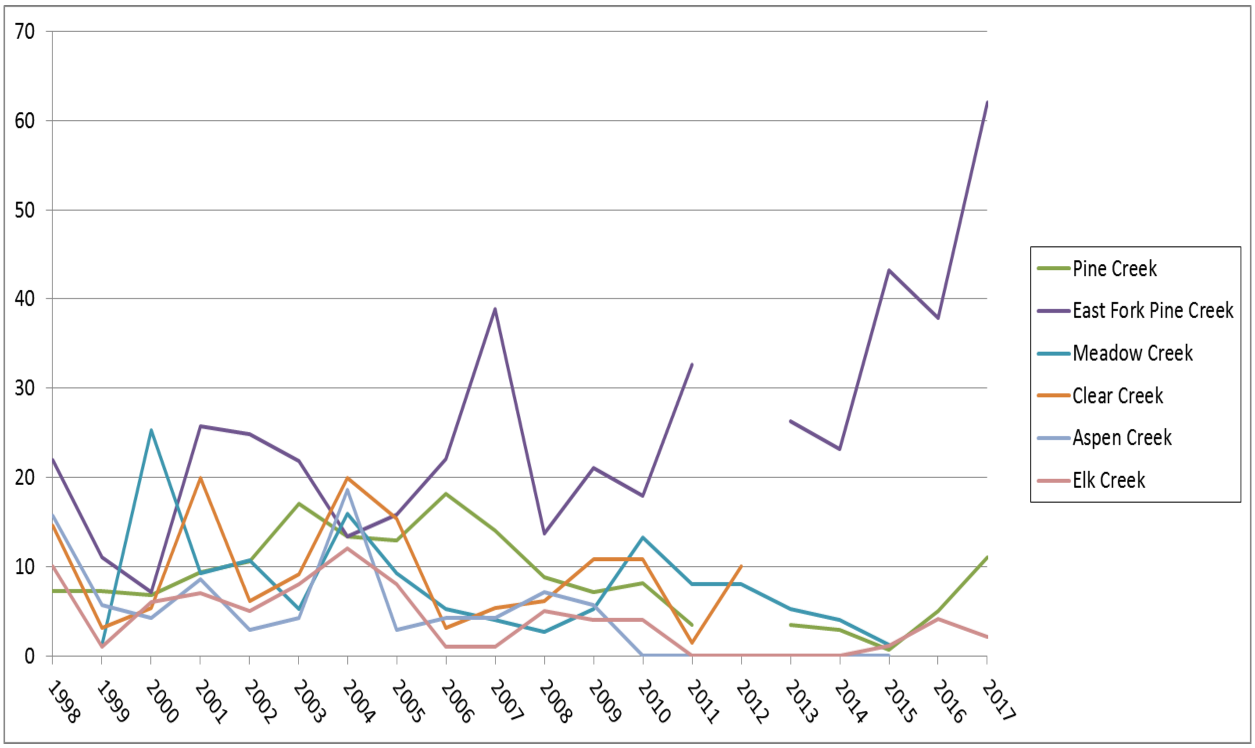



Figure 13. Redd counts in Pine Creek survey reaches, 1998-2017 (T. Bailey, ODFW, unpublished data).

<u>Proposed Pine Creek Monitoring</u>

- Resample distribution, relative abundance, and hybridization of bull and brook trout using systematic electrofishing at 5-10 year intervals
- PIT-tag bull trout collected during sampling
- Operate PIT-tag antenna arrays to monitor potential subadult out migration and returns of migratory adults

*North Fork Malheur and Upper Malheur Core Areas*

A study of the genetic structure of bull trout in the Malheur basin (DeHaan et al. 2007) supports the grouping of populations into the North Fork and upper Malheur core areas. Distribution and abundance of juveniles, resident adults, and brook trout and distribution of migratory forms have been sampled in the upper Malheur (Schwabe et al. 2003). Distribution of migratory forms in the North Fork Malheur has also been documented using telemetry (Schwabe et al. 2000) and fish trapped in Beulah reservoir (e.g., BOR 2015).

Spawning surveys have been conducted in the North Fork Malheur core area since 1992 (Perkins 2013; Ramirez 2017) (Figures 14 and 15).

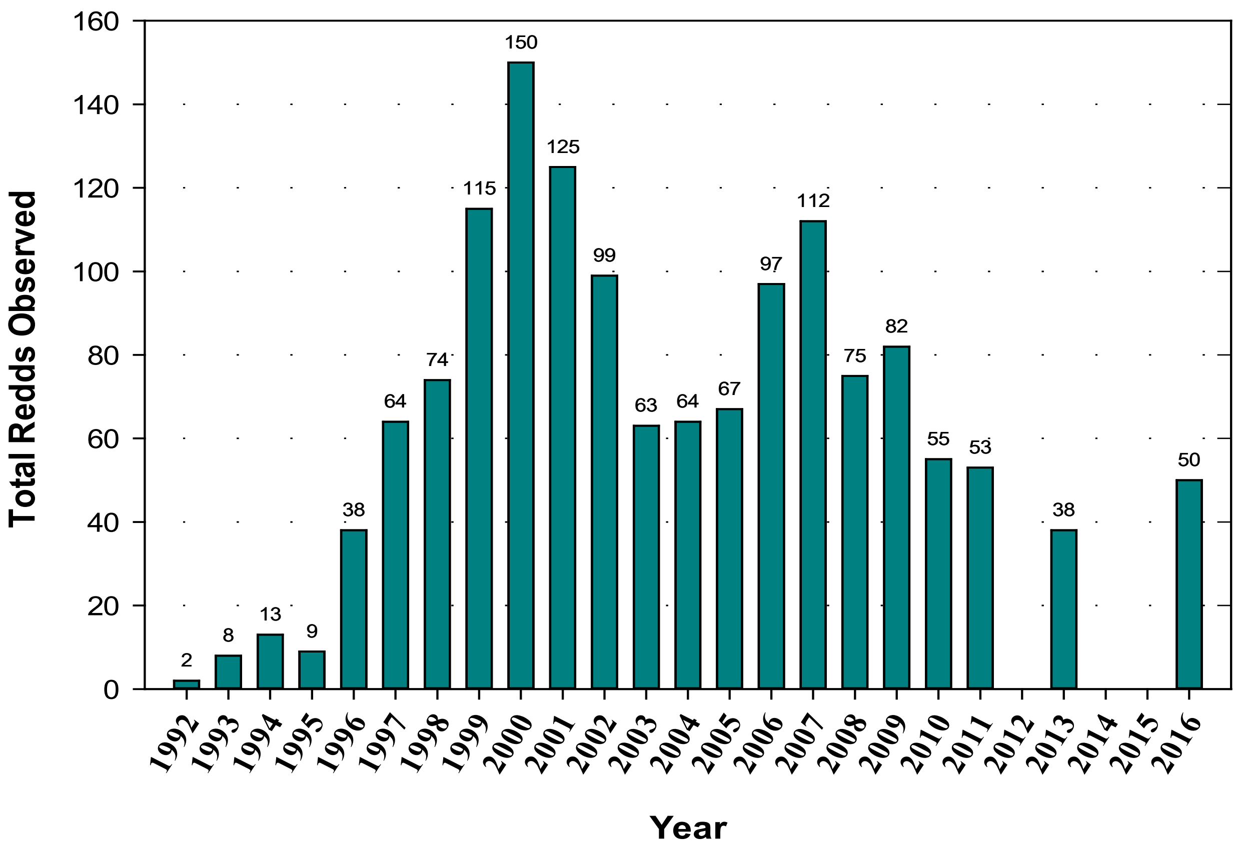



Figure 14. Total redds observed in the reaches surveyed in the North Fork Malheur core area (Ramirez 2017).

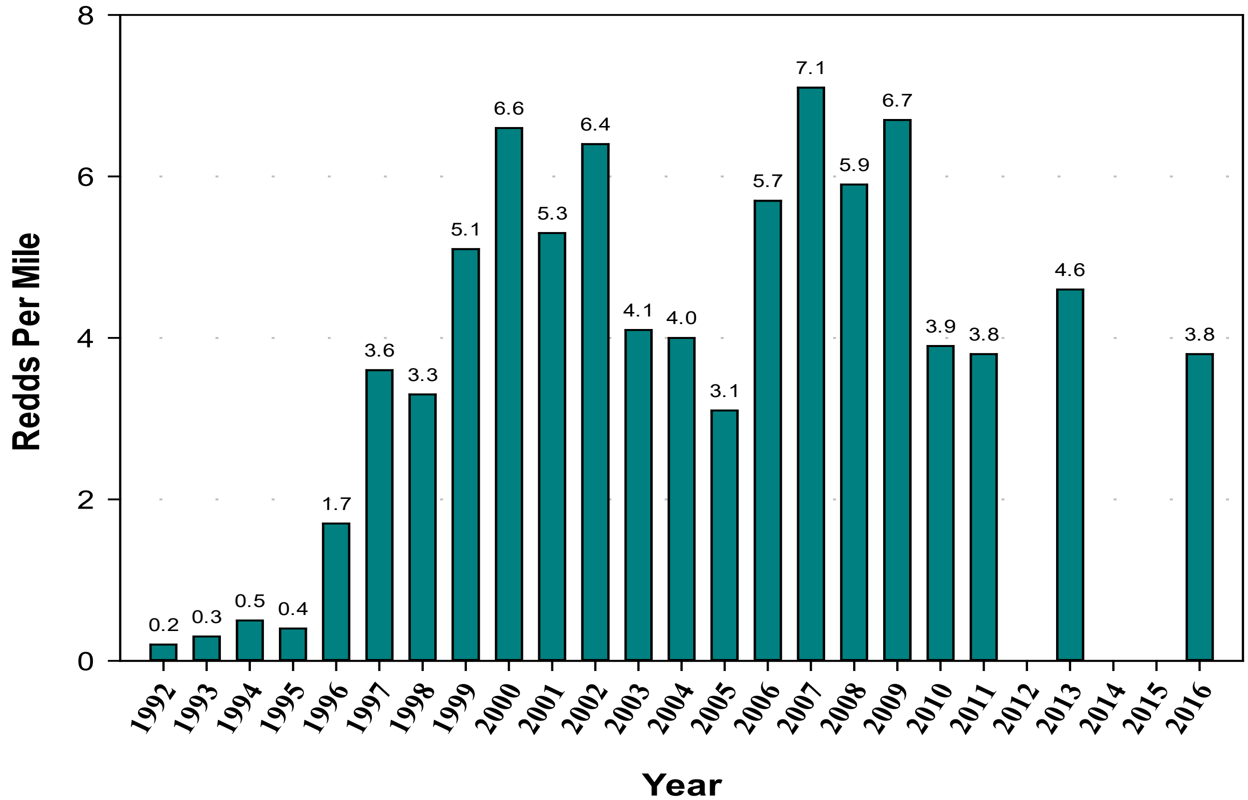



Figure 15. Redds/mile observed in the reaches surveyed in the North Fork Malheur core area (Ramirez 2017).

However, from these datasets it is difficult to interpret abundance and trend over time because the number of surveys, timing, and reaches surveyed have varied. So the extent to which the values reflect changes in the populations vs. changes in the surveys is unclear. Redds/mile is a particularly problematic metric since those values can be strongly influenced by the quality, spawning use, and length of the reaches surveyed. For example, redd/mile values for Little Crane Creek were larger in 2016 than in 2001 (Table 3). However, 2001 was the highest total redd count on record, and more than 3 times the miles of stream were surveyed than in 2016. So it is uncertain how much the redds/mile value was influenced by differences in the reaches surveyed.

Table 3. Redd counts and survey miles for Crane Creek, 2001 and 2016 [data from Ramirez (2017)].

| Year | Redds | Miles | Redds/Mile |
|---|---|---|---|
| 2001 | 74 | 6.2 | 12 |
| 2016 | 27 | 1.7 | 15.9 |

Redd size was measured in previous surveys to help estimate numbers of small redds from resident forms versus larger redds from migratory forms (Figure 16). The small and large classes indicate both resident and migratory life histories are present; however, the medium size class, which accounted for the largest number of redds, ranged from 0.5-1.5m. As indicated in Figure 4, this size class includes redds of both resident and fluvial fish. Consequently, it would be more informative to measure redd lengths and apply a criteria from Figure 4 (i.e., <1m vs. >1m) to classify resident versus fluvial redds.

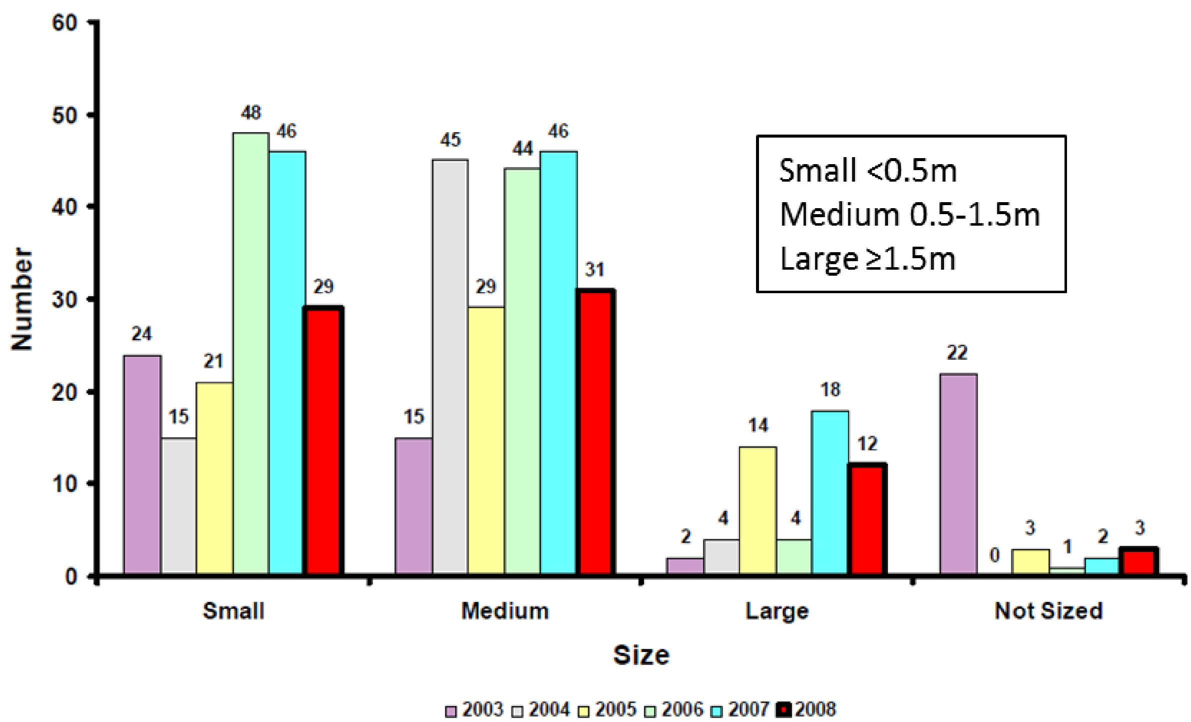



Figure 16. Size of bull trout redds in the North Fork Malheur core area (Perkins 2013).

Brook trout do not occur in the North Fork Malheur core area; however, the presence of brook trout and uncertainties concerning spawning timing are considerations in the upper Malheur core area. As Perkins (2013) stated, "In the Upper Malheur Watershed, distinguishing between bull trout and brook trout redds is impossible without identifying the fish creating each redd. Very few fish were identified and associated with redds." The number of bull trout redds in the upper Malheur was estimated as the number recorded prior to September 15. This was based on these assumptions: 1. the bull trout spawning period in the upper Malheur was the same as the North Fork Malheur (i.e., "bull trout began to spawn in late August, peaked prior to mid-September…" Perkins (2013) and 2. brook trout don't spawn until mid-September. However, the spawning period of bull trout in the upper Malheur has not been determined. It is possible the spawning period for upper Malheur bull trout is more similar to that of the upper John Day core area, which peaks in mid-October (Moore et al. 2005), since the upper Malheur is closer to the upper John Day than to the North Fork Malheur. As previously discussed, the spawning timing of brook trout and degree of overlap with bull trout are unknown so it is not possible to distinguish bull trout redds from brook trout redds. Hybrids in the population (DeHaan et al. 2009) are also evidence of overlap in spawning timing.

The redd count data for the upper Malheur (Figure 17) suggests both the counts of redds classified as bull trout redds (counts prior to September 15) and total redds (bull trout and brook trout) appear to have declined since about 2007. Besides the problems discussed concerning classifying bull trout redds, it is also curious that brook trout redds (the total redds minus the bull trout redds) appear to have also declined, which is inconsistent with the high numbers of brook trout reported in the conservation strategy (MTAC, undated).

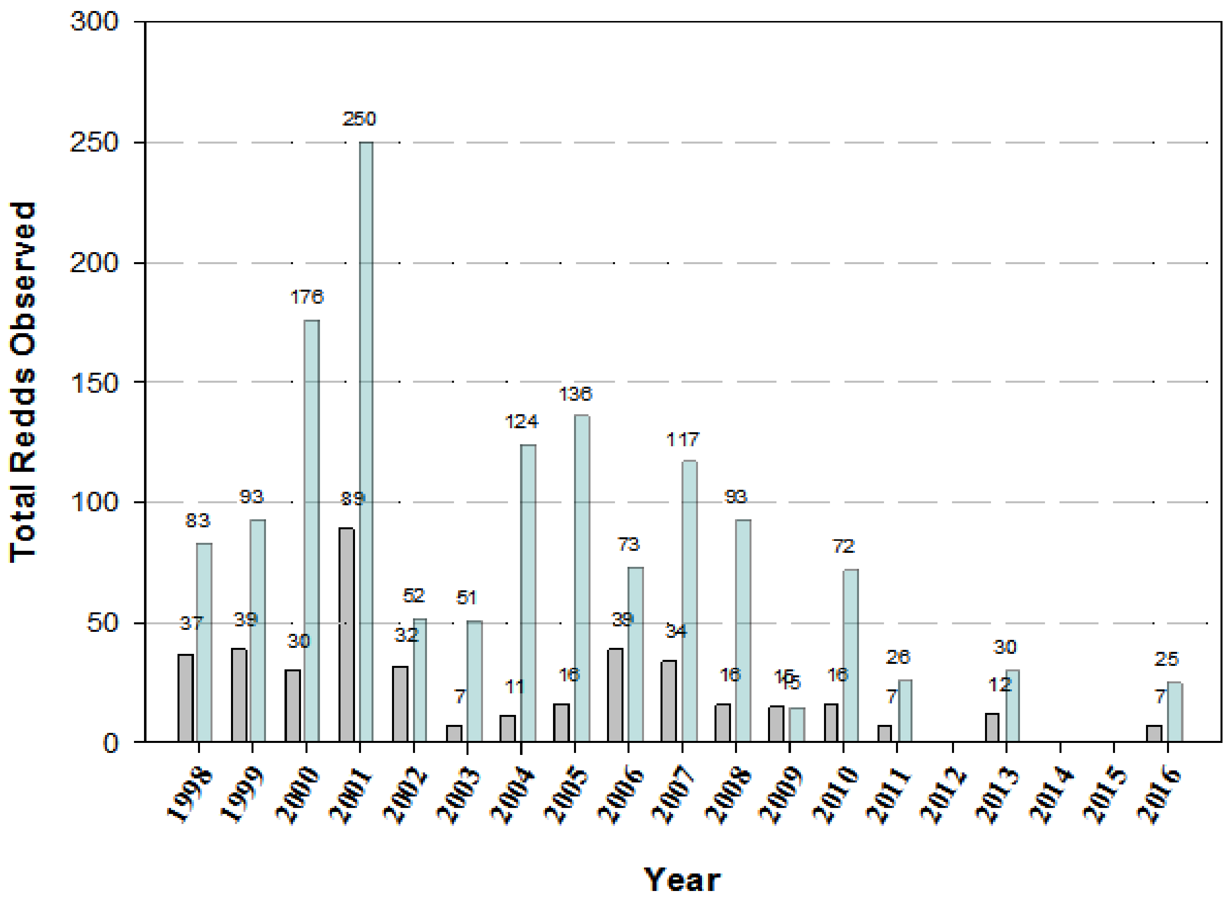



Figure 17. The number of redds observed in the upper Malheur River watershed from 1998-2016. The gray bars represent the number of redds observed prior to September 15 (assumed bull trout redds) and the blue bars represent the total number of redds observed (bull trout and brook trout) (Ramirez 2017).

Proposed North Fork Malheur Monitoring

- Sample (eDNA and/or electrofish) upper Crane Creek (Appendix figure 4) for presence and distribution of bull trout

  It is the only patch identified as high probability of bull trout occurrence that has not been sampled.

- Conduct initial extensive redd counts to identify future routine index survey reaches and the relationship between index reaches and the total redd distribution. Thereafter, conduct extensive redd counts every 8-10 years or after a major habitat change to determine any changes in distribution and necessary changes to index survey reaches.

- Conduct annual or biannual redd counts 2 times/season (mid-September and first week in October) in index reaches identified from extensive surveys and previous surveys

  Bull trout in the North Fork Malheur start spawning in late August, peak prior to mid-September, and decline into October; about 75-80% of the spawning occurs prior to mid-September (Perkins 2013). During 2008-2011, reaches were surveyed twice: a few days prior to Sept. 15 and around the end of September. Based on redd visibility data, Perkins (2013) concluded that the first survey would identify at least 70% of redds from the start of spawning and the second survey would detect at least 70% of the redds created after the first survey. Those detection probabilities for the survey intervals are consistent with those measured in other areas (Walla Walla and Little Minam) (data from Howell and Sankovich 2012; see previous discussion).

  Demographic monitoring related to the terms and conditions for operation of Beulah Reservoir includes participation of Bureau of Reclamation (BOR) in redd surveys (BOR 2018).

- Measure redd length and fish size class on occupied redds to determine migratory and resident components

Proposed Upper Malheur Monitoring

- Discontinue redd counts due to the confounding effect of brook trout present

- Combine bull trout and brook trout monitoring with the evaluation of the brook trout eradication project

  A combination of chemical treatment using rotenone to eradicate brook trout and construction of barriers has been proposed for the upper Malheur (MTAC, undated). Specific long term monitoring plans will depend on finalizing the eradication plans and development of a project evaluation.

Key attributes for inclusion:

1. Distribution and relative abundance of bull trout, brook trout, and hybrids
   For example, systematic electrofishing and/or snorkeling could be used (e.g., Howell 2018; Wilkison and Trainer 2017), which could include hybrid identification based on phenotypic characteristics.

2. Abundance of migratory adults
   Maintaining and restoring migratory forms of bull trout is key to conserving the life history diversity and recovery of populations in the upper Malheur. The conservation strategy (MTAC, undated), which addresses the brook trout eradication program, also includes construction of temporary barriers to prevent reinvasion of brook trout from downstream reaches. The conservation strategy acknowledges the potential for these barriers to also impede movement of bull trout and calls for monitoring to evaluate this. One possibility mentioned is the use of traps in conjunction with the barriers, which would permit selective passage and sampling (e.g., enumeration, lengths) of bull trout.

*John Day Core Areas*

The John Day River Basin is comprised of three bull trout core areas: Upper John Day (UJD), Middle Fork John Day (MFJD), and North Fork John Day (NFJD). Patch occupancy probabilities have been modeled by the USFS for eDNA sampling (https://www.fs.fed.us/rm/boise/AWAE/projects/ClimateShield/monitoring.html), the Bull Trout Vulnerability Assessment (Dunham 2014), and M. Meeuwig (ODFW, unpublished data). Of those, only Meeuwig's work included sampling fish in the UJD and MFJD. Utah State University (USU) (Budy et al. 2006; 2007) sampled portions of the upper NFJD and Desolation Creek. ODFW et al. sampled Vinegar Creek [Middle Fork John Day (MFJD)] in 1999. The USFS and CTUIR have also sampled eDNA in various locations (Appendix figures 6-8). Extensive distribution and life history information is available from research studies in the UJD and NFJD (Bellerud et al. 1997 and following years).

<u>Proposed John Day Patch Occupancy Monitoring</u>

- When M. Meeuwig's sampling data and analyses are available, determine further needs for sampling patch occupancy and distribution within those patches

- Coordinate additional eDNA sampling based on unsampled or undersampled patches (Appendix figures 6-8)

Proposed John Day Genetic Monitoring

- Determine population/metapopulation structure within and among the John Day core areas

  Very limited data is available on population and metapopulation structure in the John Day (e.g., Spruell et al. 2003; Ardren et al. 2011). Additional tissue samples were collected in 2002-2003 but not analyzed (P. Howell, unpublished data), and by Meeuwig (ODFW, unpublished data) for estimating $N_e$ and $N_b$. However, sample sizes collected were inadequate for $N_e/N_b$ analyses. Population and metapopulation structure would be helpful in identifying population units to monitor and understanding gene flow and connectivity among populations.

*UJD and MFJD Core Areas*

Since 2001, spawning surveys in the John Day Basin have been largely limited to Baldy (NFJD), upper Big (MFJD), and Call and North Fork Reynolds (UJD)) creeks (Table 4).

Table 4. Bull trout redd counts for the John Day core areas, 2001-2017 (ODFW, unpublished data).

| Stream (core area) | | Year | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Miles | '01 | '02 | '03 | '04 | '05 | '06 | '07 | '08 | '09 | '10 | '11 | '12 | '13 | '14 | '15 | '16 | '17 |
| Baldy (NFJD) | 1.3 | 2 | 3 | 3 | 3 | 7 | 3 | 0 | 2 | NS | NS | NS | 5 | 2 | 0 | NS | NS | 1 |
| Upper Big (MFJD) | 1.3 | 23 | 13 | 6 | 1 | 2 | 1 | 0 | NS | 0 | NS | NS | 0 | 0 | NS | NS | NS | NS |
| Call (UJD) | 1.7 | 12 | 3 | 6 | 13 | 5 | 0 | | NS | 0 | 0 | NS | 2 | 1 | NS | 0 | NS | 4 |
| NF Reynolds (UJD) | 1.5 | 5 | 3 | 4 | 2 | 0 | 5 | 4 | NS | 1 | 0 | NS | 1 | 1 | NS | 1 | NS | 2 |

NS=no survey

While declines may be occurring, in Big Creek for example, any trends are confounded by a reduction in the number of surveys/season and the lack of surveys in recent years. Lower Big Creek was also surveyed in 2017. Data on the size of the fish observed during the surveys suggests that the population in upper Big Creek may be small resident forms, whereas larger fluvial forms may be spawning in lower Big Creek (Table 5).

Table 5. Bull trout redd counts, dates of surveys, and size of fish observed in upper and lower Big Creek, 2001-2017 (ODFW, unpublished data) (NS=no survey).

| | Year | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stream | '01 | '02 | '03 | '04 | '05 | '06 | '07 | 08 | '09 | '10 | '11 | '12 | '13 | '14 | '15 | '16 | '17 |
| Upper Big | **23*** | **13** | **6** | **1** | **2** | **1** | **0** | NS | **0** | NS | NS | **0** | **0** | NS | NS | NS | NS |
| Surveys | 10/2 | 10/2 | 10/2 | 9/30 | 9/20 | 10/6 | 10/11 | | 11/3 | | | 10/8 | 10/25 | | | | |
| | 10/19 | 10/18 | 10/21 | 10/21 | 10/20 | | | | | | | | | | | | |
| Lower Big | | | | | | | | | | | | | | | | | 3** |
| Surveys | | | | | | | | | | | | | | | | | 9/28 |

*92 fish <12”

**1 fish 12-18”

The only extensive, census spawning surveys in the UJD and MFJD were conducted in 2005 (Moore et al. 2006). Those redd counts also suggest that the three streams surveyed in the UJD and MFJD (boxes in Table 6) may not be representative of the other, possibly larger, populations (circles in Table 6) in those core areas.

Table 6. Census bull trout redd counts in the UJD and MFJD, 2005 (Moore et al. 2006).

| Subbasin | Stream | Reach | Times Surveyed | Date of First Survey | Date of Last Survey | Redd Count |
|---|---|---|---|---|---|---|
| Middle Fork John Day | Clear Creek | 1 | 5 | 9/6/2005 | 10/25/2005 | 1 |
| | | 2 | 5 | 9/6/2005 | 10/25/2005 | 0 |
| | | 3 | 5 | 9/6/2005 | 11/2/2005 | 5 |
| | | 4 | 5 | 9/6/2005 | 11/1/2005 | 17 |
| | Granite Boulder Creek | 1 | 5 | 9/12/2005 | 10/31/2005 | 0 |
| | | 2 | 5 | 9/12/2005 | 10/31/2005 | 1 |
| | Deadwood Creek | 1 | 4 | 8/30/2005 | 10/25/2005 | 0 |
| | | 2 | 4 | 8/30/2005 | 10/25/2005 | 0 |
| | Big Creek | 1 | 4 | 8/30/2005 | 10/24/2005 | 0 |
| | | 2 | 4 | 8/30/2005 | 10/24/2005 | 0 |
| | | 3 | 4 | 8/30/2005 | 10/24/2005 | 1 |
| | | 4 | 4 | 8/30/2005 | 10/24/2005 | 0 |
| Upper John Day | Mossy Gulch | 1 | 5 | 8/31/2005 | 11/1/2005 | 1 |
| | North Reynolds Creek | 1 | 5 | 8/21/2005 | 11/1/2005 | 0 |
| | | 2 | 5 | 8/31/2005 | 10/27/2005 | 3 |
| | Call Creek | 1 | 5 | 9/1/2005 | 11/2/2005 | 2 |
| | | 2 | 4 | 9/1/2005 | 10/20/2005 | 2 |
| | Rail Creek | 2 | 3 | 9/8/2005 | 10/8/2005 | 3 |
| | | 3 | 3 | 9/8/2005 | 10/26/2005 | 11 |
| | | 4 | 3 | 9/8/2005 | 11/1/2005 | 6 |
| | Roberts Creek | 1 | 5 | 9/6/2005 | 11/3/2005 | 19 |
| | Deardorff Creek | 1 | 5 | 8/25/2005 | 11/3/2005 | 1 |
| | | 2 | 5 | 8/25/2005 | 11/2/2005 | 1 |
| | | 3 | 5 | 8/25/2005 | 11/2/2005 | 9 |
| | | 4 | 4 | 9/1/2005 | 10/17/2005 | 17 |
| | Reynolds Creek | 1 | 5 | 9/7/2005 | 11/1/2005 | 1 |
| | | 2 | 4 | 9/12/2005 | 10/9/2005 | 2 |
| | | 3 | 4 | 9/12/2005 | 10/19/2005 | 0 |
| | Indian Creek | 1 | 4 | 8/31/2005 | 10/25/2005 | 5 |
| | | 2 | 4 | 8/31/2005 | 10/25/2005 | 5 |
| | John Day River | 1 | 5 | 9/7/2005 | 10/25/2005 | 0 |
| | | 2 | 5 | 9/7/2005 | 11/2/2005 | 16 |
| | | 3 | 5 | 9/7/2005 | 11/2/2005 | 10 |
| | | 4 | 6 | 9/7/2005 | 11/2/2005 | 15 |

The limited spawning survey data, more extensive trapping data for the UJD (Bellerud et al. 1997 and following years), occupancy and genetic sampling (M. Meeuwig, ODFW, unpublished data) suggest low population sizes and distribution and small numbers of fluvial forms, particularly in the MFJD.

Proposed UJD and MFJD Monitoring

- Conduct initial extensive redd counts to determine spawning distribution and future routine index survey reaches

- Conduct redd counts 2 times/season (mid-September and mid-October) alternating streams every 2 years after establishing index survey reaches

- Conduct extensive redd counts every 8-10 years or after a major habitat change to determine any changes in distribution and necessary changes to index survey reaches

- Measure redd length and size class of bull trout observed to determine migratory and resident components

- Systematically electrofish Indian Creek to determine distribution and relative abundance

  Indian Creek hasn't been surveyed in recent years, and there are concerns about possible effects of past fires on the population. The population likely consists of resident fish since it is isolated by irrigation use lower in the drainage.

- Systematically snorkel the upper main stem every 8-10 years to determine distribution and relative abundance of brook trout and bull trout

  Brook trout occur in the upper reaches of the main stem John Day River (e.g., Appendix figure 6), but existing data do not suggest they are widespread or abundant. Snorkel counts would be preferable to electrofishing because of possible injury of large, fluvial adult bull trout also present in the upper main stem.

*NFJD Core Area*

Brook trout occur in the upper main stem of the NFJD and some tributaries. Where brook trout overlap with bull trout, it is difficult to distinguish bull trout redds from brook trout redds, particularly for small, resident forms. Some of the NFJD streams, like Baldy Creek, also contain a high proportion of decomposed granite that can also make the redds difficult to detect (Hemmingsen et al. 2001b).

USU conducted systematic snorkeling and mark-recapture in the upper NFJD in 2005 and 2006 (Budy et al. 2006; 2007) (Figure 18).

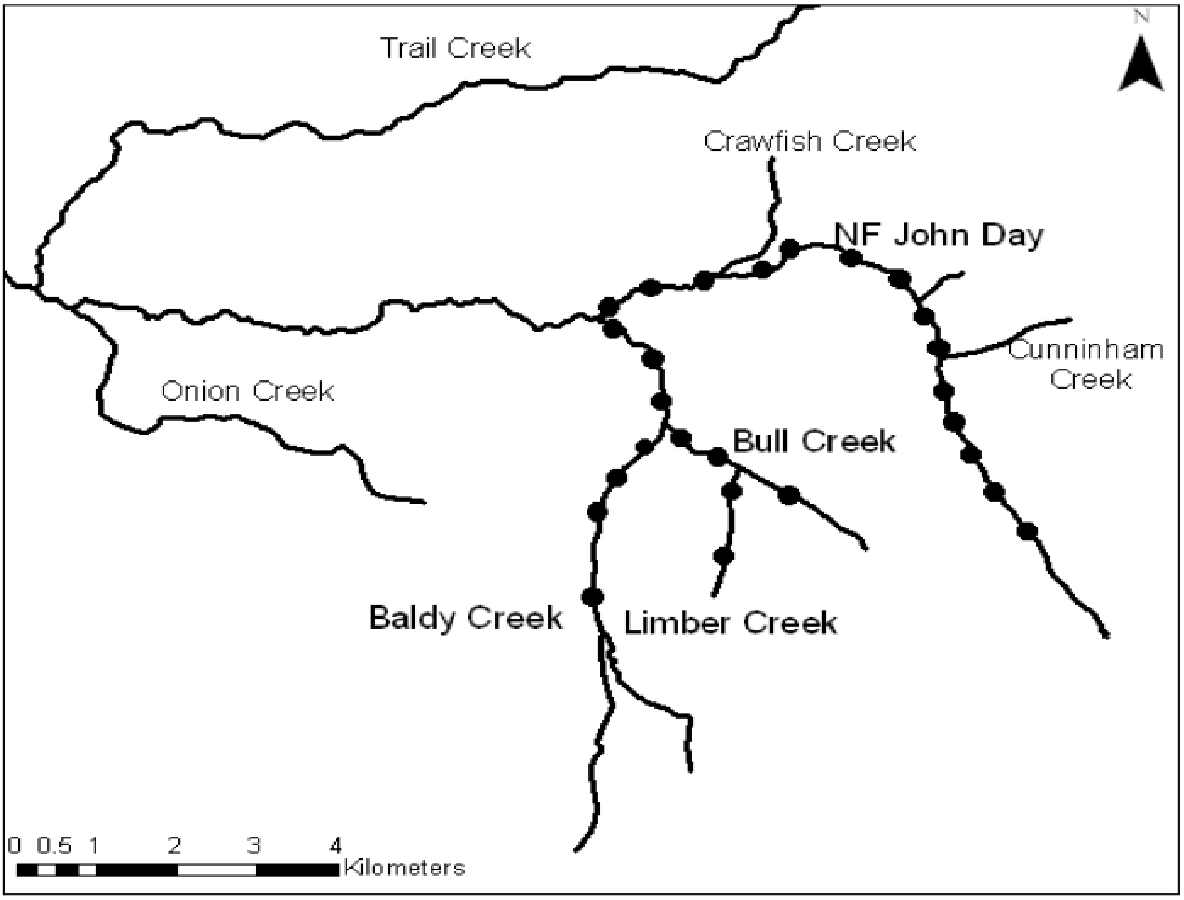



Figure 18. Map of USU sampling locations in the NFJD in 2006. The main stem downstream to Trail Creek was sampled in 2005 (Budy et al. 2006; 2007).

The data included estimates of bull trout and brook trout densities, population estimates, and size, which is useful for estimating relative numbers of large, fluvial adults. ODFW/USFS also systematically sampled the distribution and relative abundance of bull and brook trout using electrofishing in some upper NFJD tributaries in 1996 (Table 7).

Table 7. Distribution and relative abundance of char sampled in systematic electrofishing reaches in tributaries of the NFJD, 1996 (Bellerud et al. 1997).

| | Bull Trout Zone | | Sympatric zone | | | Brook Trout Zone | | BRK/BUL Hybrid | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Length (km) | Bul /100m | Length (km) | BUL /100m | BRK /loom | Length (km) | BRK /100m | Length (km) | HYB /100m | Stream length (km) |
| **North Fork John Day River** | | | | | | | | | | |
| Crane Cr. | | | 0.5 | 4 | 1 | 12.2 | 4.7 | | | 13.75 |
| Baldy Cr. | 5.5 | 8.5 | 1.0 | 4.5 | 1.5 | 1.0 | 1 | | | 8.0 |
| Cunningham Cr. | 0.5 | 1.5 | | | | | | 0.5 | 1 | 1.75 |
| Crawfish Cr. | | | 1.0 | 5 | 12 | 4.5 | 17.8 | | | 6.0 |

Extensive snorkel surveys of South Fork Desolation conducted by Howell, Hemmingsen, and Tatum (unpublished data) in the early-mid 1990s and more recently in 2006 by USU (Al-Chockhachy, unpublished data) have documented the distribution and relative abundance of juvenile and resident adult sized fish. Although larger fluvial bull trout have been observed during snorkeling surveys in the main stem of Desolation Creek (P. Howell, unpublished data) and were reported spawning by Errol Claire (ODFW, pers. com.), no fluvial-sized redds have been observed in South Fork Desolation (Howell and Sankovich, unpublished data) and no juveniles have been found in North Fork Desolation (P. Howell, unpublished data).

The limited spawning survey data and the distribution and abundance data discussed above, suggest generally low population sizes and numbers of fluvial forms.

<u>Proposed NFJD Monitoring</u>

- Systematically snorkel the upper NFJD and Baldy Creek in late summer every 5 years to determine distribution, relative abundance, and size class of bull trout and brook trout Snorkeling would be preferable to electrofishing to minimize possible injury to migratory adults that occur in these streams and the inefficiency of electrofishing in the main stem of the NFJD.
- Systematically electrofish or snorkel Crane, Onion, Crawfish, Cunningham, upper Granite, Bull Run, Boundary, and Deep creeks every 5-10 years to determine distribution and relative abundance of bull trout and brook trout
  Distribution and relative abundance in these streams is currently unknown.
- Conduct initial extensive redd counts to determine spawning distribution, fluvial vs. resident abundance, and future routine index survey reaches in Trail and Clear creeks, which do not have brook trout. After index reaches have been determined, conduct biennial redd counts 2 times/season alternating streams every 2 years.
- Conduct extensive redd counts every 8-10 years or after a major habitat change in Trail and Clear creeks to determine any changes in distribution and necessary changes to index survey reaches
- Measure redd length and size class of bull trout observed to determine migratory and resident components
- Systematically snorkel main stem Desolation Creek (July/August) and South Fork Desolation Creek (mid-late September) every 5-10 years. Data on redd numbers,

location, and size in South Fork Desolation should also be collected during snorkel surveys.

Surveys in main stem Desolation would be helpful in estimating the distribution and relative abundance of migratory bull trout. Surveys in South Fork Desolation in September would also contribute information on fish and redd abundance and distribution of potential migratory adults.

*Walla Walla Core Area*

Extensive distribution, life history, abundance, and survival information is available from research studies in Mill Creek and the Walla Walla River (Howell and Sankovich 2012; Schaller et al. 2014 and related papers; Howell et al. 2016). These data also indicate all of the patches have been sampled for occupancy. Brook trout distribution in the Walla Walla is limited to Big Spring Creek and East Fork Walla Walla River (lower Walla Walla). The brook trout reach shown for Henry Canyon/Mill Creek in Appendix figure 9 appears to be an error in the database (D. Crabtree and L. Boe, USFS, pers. com.)

Mill Creek and Low Creek Populations

As previously discussed, the Mill Creek fluvial population and the Low Creek resident population are genetically and demographically distinct local populations. Census redd counts in Mill Creek and Low Creek were made during 1996-2007 in the reaches shown in Figure 19.

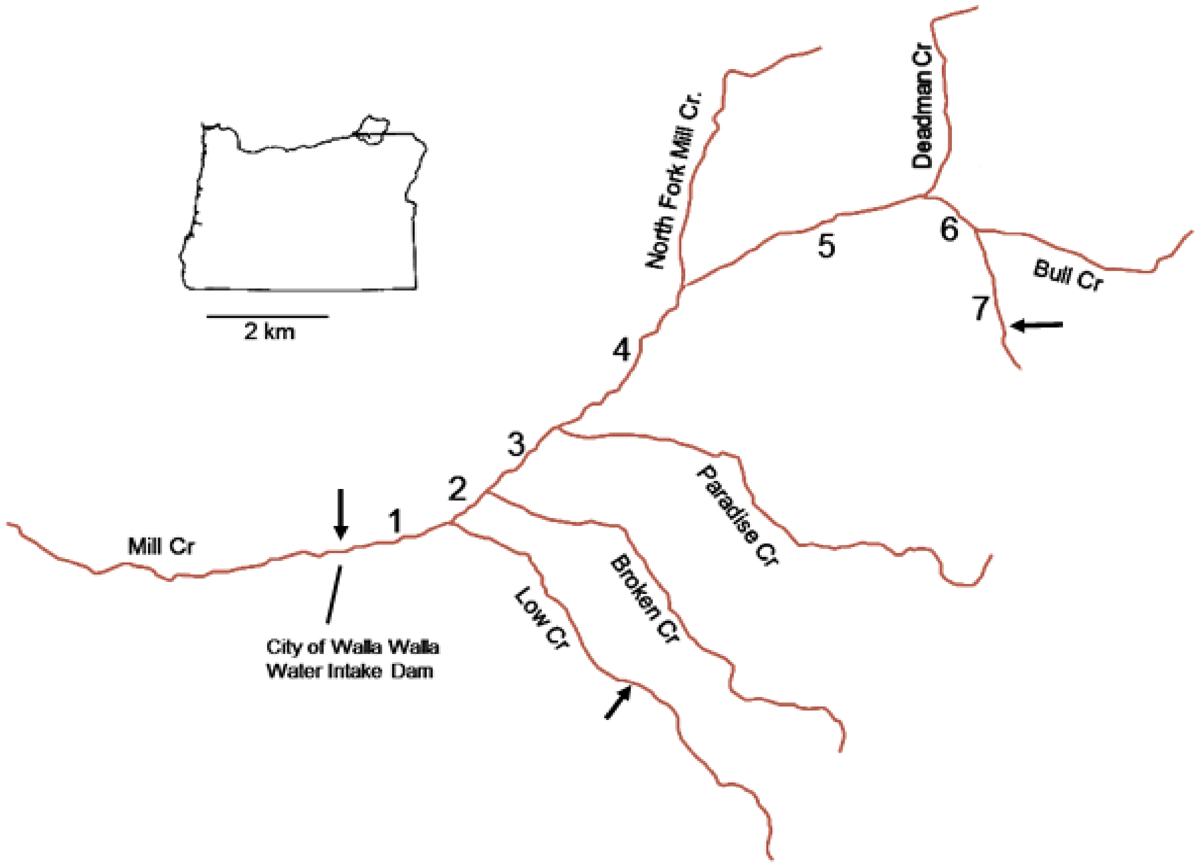



Figure 19. Locations of bull trout spawning survey reaches in Mill Creek and Low Creek. Breaks between reaches are at arrows and tributary junctions.

Reaches 4 and 5 accounted for most (67%) of the total redds in Mill Creek. If the counts in those reaches were expanded by 33%, the mean expanded redd count would be the same as the mean total redd count for 1996-2007 with a SD of 7% (Table 8) and closely track the trend in total redds (Figure 20). There was also very little variation in the distribution of redds (i.e., proportion of redds in reaches 4 and 5 combined) during years of high abundance (2001-2002) vs. low abundance (2006-2007), when differences in distribution might be more apparent.

Table 8. Total redds in Mill Creek reaches 1-7 compared to the expansion of redds in reaches 4 and 5 by 33% based on their mean proportion of the total redds during 1996-2007 (67%).

| | Total redds | Expansion of reaches 4 + 5 as a percentage of total redds | |
|---|---|---|---|
| 1996 | 98 | 118 | |
| 1997 | 89 | 84 | |
| 1998 | 101 | 89 | |
| 1999 | 133 | 108 | |
| 2000 | 127 | 98 | |
| 2001 | 180 | 96 | |
| 2002 | 173 | 104 | |
| 2003 | 106 | 101 | |
| 2004 | 97 | 98 | |
| 2005 | 95 | 106 | |
| 2006 | 56 | 99 | |
| 2007 | 58 | 98 | |
| | | 100 | Mean |
| | | 7 | SD |

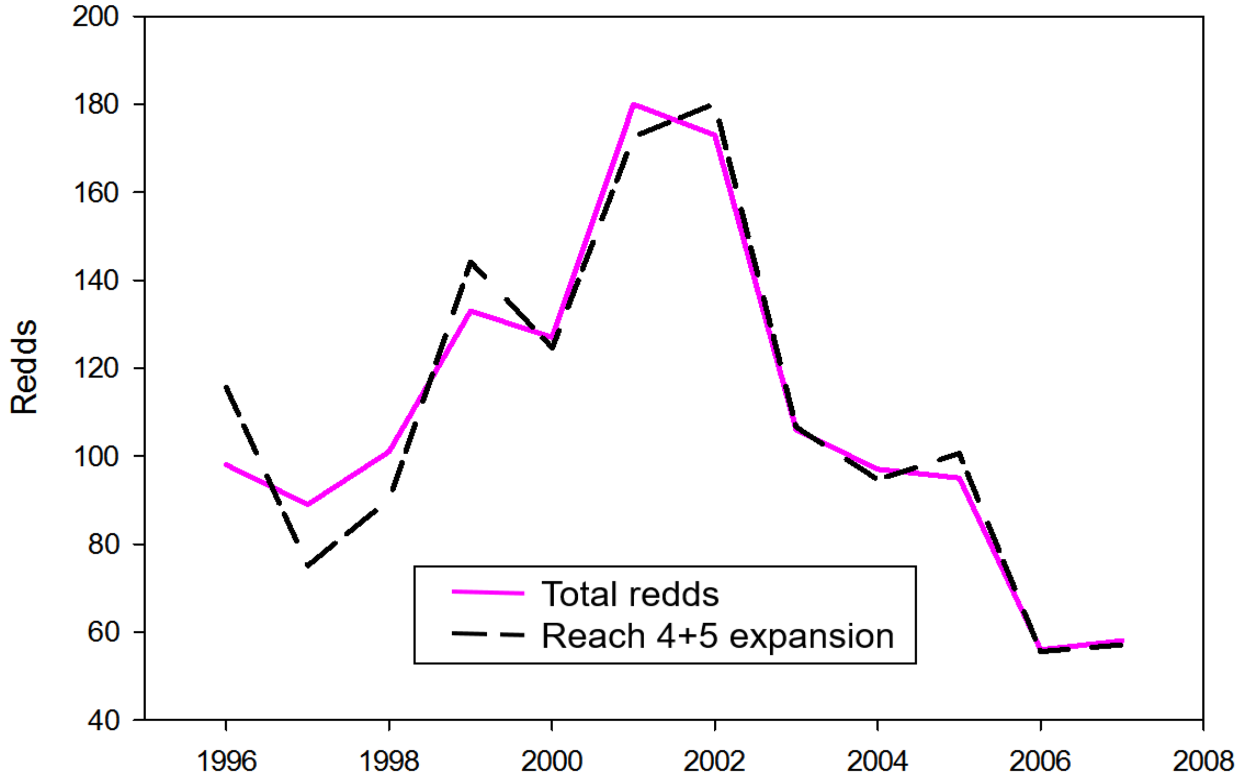



Figure 20. Total redds in Mill Creek vs. expanded total redds based on reaches 4 and 5.

Video counts of bull trout moving upstream through the ladder at the Bennington diversion dam have been recorded (Table 9). These provide an estimate of migratory bull trout in the Mill Creek population using lower Mill Creek, Yellowhawk Creek, and the lower Walla Walla River. The apparent declining numbers are a concern, especially in light of the decline in the spawning population and subadult survival (Howell et al. 2016).

Table 9. Bull trout passing upstream in Mill Creek through the ladder at Bennington diversion dam, 2004-2014 (USACE Walla Walla, unpublished data).

| Year | Bull trout |
|---|---|
| 2004 | 35 |
| 2005 | 23 |
| 2006 | 11 |
| 2007 | 3 |
| 2008 | no count |
| 2009 | 6 |
| 2010 | 5 |
| 2011 | 3 |
| 2012 | 0 |
| 2013 | 0 |
| 2014 | 0 |
| 2015 | 0 |
| 2016 | 0 |

Proposed Mill Creek Monitoring

- Conduct annual redd counts twice/season in reaches 4 and 5

  Adult abundance declined by 63% during 2006-2010 (Howell et al. 2016). Since then redd surveys have been partial and sporadic to non-existent. The substantial decline and low abundance levels warrant more consist and frequent monitoring.

- Conduct extensive redd counts every 8-10 years or after a major habitat change to determine any changes in distribution and necessary changes to index survey reaches

- Consider installing a fish counter in the ladder of the City of Walla Walla diversion dam located at the downstream limit of spawning

  This would potentially eliminate the need for redd counts in Mill Creek.

- Continue upstream counts at the Bennington dam ladder (USACE)

  This will allow continued tracking of the fluvial adult population below Bennington Dam.

Proposed Low Creek Monitoring

- Conduct redd counts (twice/season) every 5-10 years and after a major habitat change. If redd counts suggest a potentially substantial decline in the population, more frequent monitoring would be warranted.

Redd counts in Low Creek have been stable (Figure 8), habitat conditions are relatively pristine, and threats to the population are low.

South Fork Walla Walla River Population

Redd surveys have been conducted in the South Fork Walla Walla since 1994 (Figure 21).

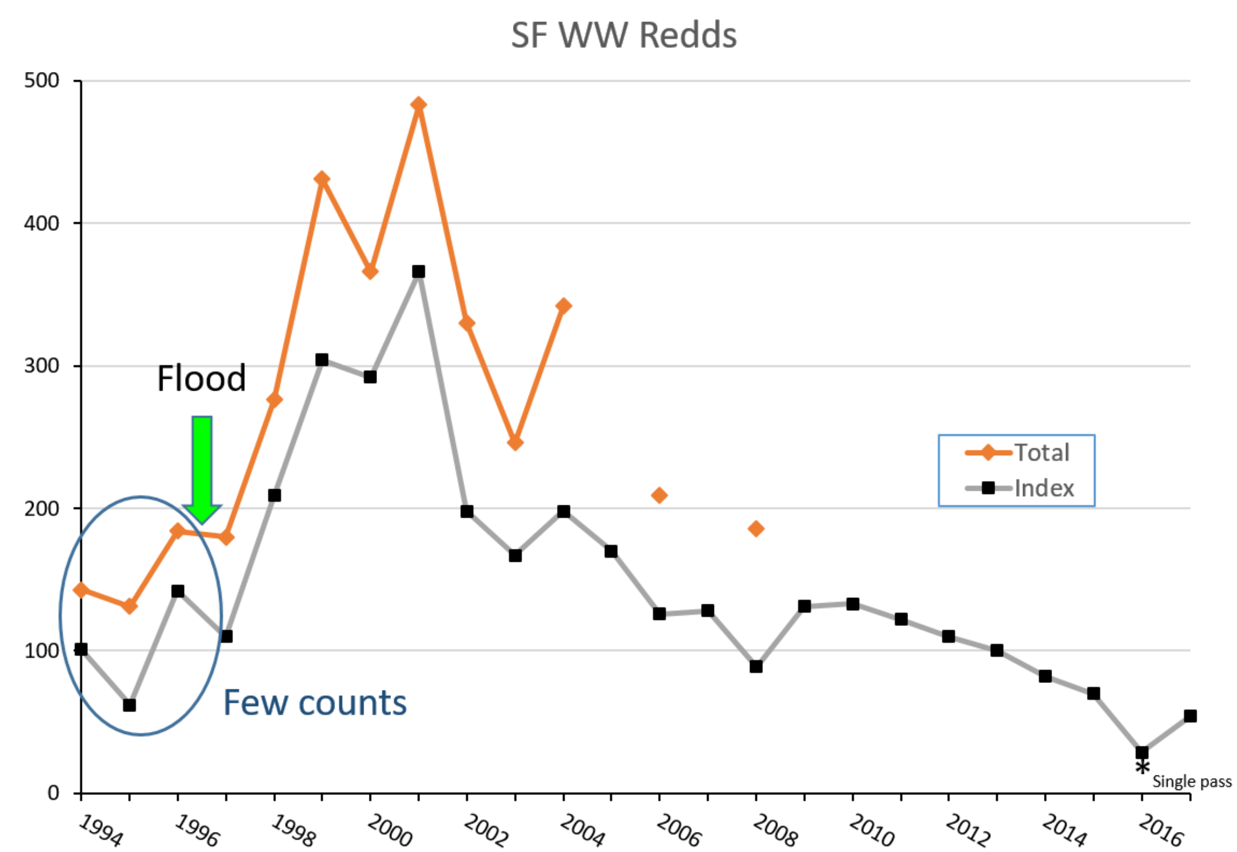



Figure 21. Redd counts in the South Fork Walla Walla (1994-2017). Total counts include all reaches outside of the index reaches surveyed that year (W. Duke, ODFW, unpublished data).

Initially only a few counts were made in a few reaches. The most extensive counts of the spawning population were made in 2003-4. Those counts indicate that a substantial number of redds occurred upstream of Table Creek outside of the index reaches (Table 10).

Table 10. Redd counts in the South Fork Walla Walla by reach, 2003-2004 (W. Duke, ODFW, unpublished data).

| Reach | 2003 | 2004 |
|---|---|---|
| Harris Park to Bear Creek | 2 | 1 |
| Bear Cr to Burnt Cabin | 5 | 3 |
| Burnt Cabin to Table Creek | 10 | 6 |
| Table Creek to Skiphorton Creek | 62 | 46 |
| Skiphorton Creek To Midpoint* | 50 | 46 |
| Midpoint to Reser* | 75 | 73 |
| Reser Creek to 2nd trib on east* | 42 | 79 |
| 2nd trib to top | | 38 |
| Skiphorton Creek | | 50 |
| Total | 246 | 342 |

*Index

Counts since 2004 have been limited to the index reaches, and the number of surveys have declined due to a reduction of personnel. In 2008 or 2009 two large log jams formed in the index reaches that may have altered the spawning distribution and skewed the redd counts in the index reaches (Figures 22 and 23).

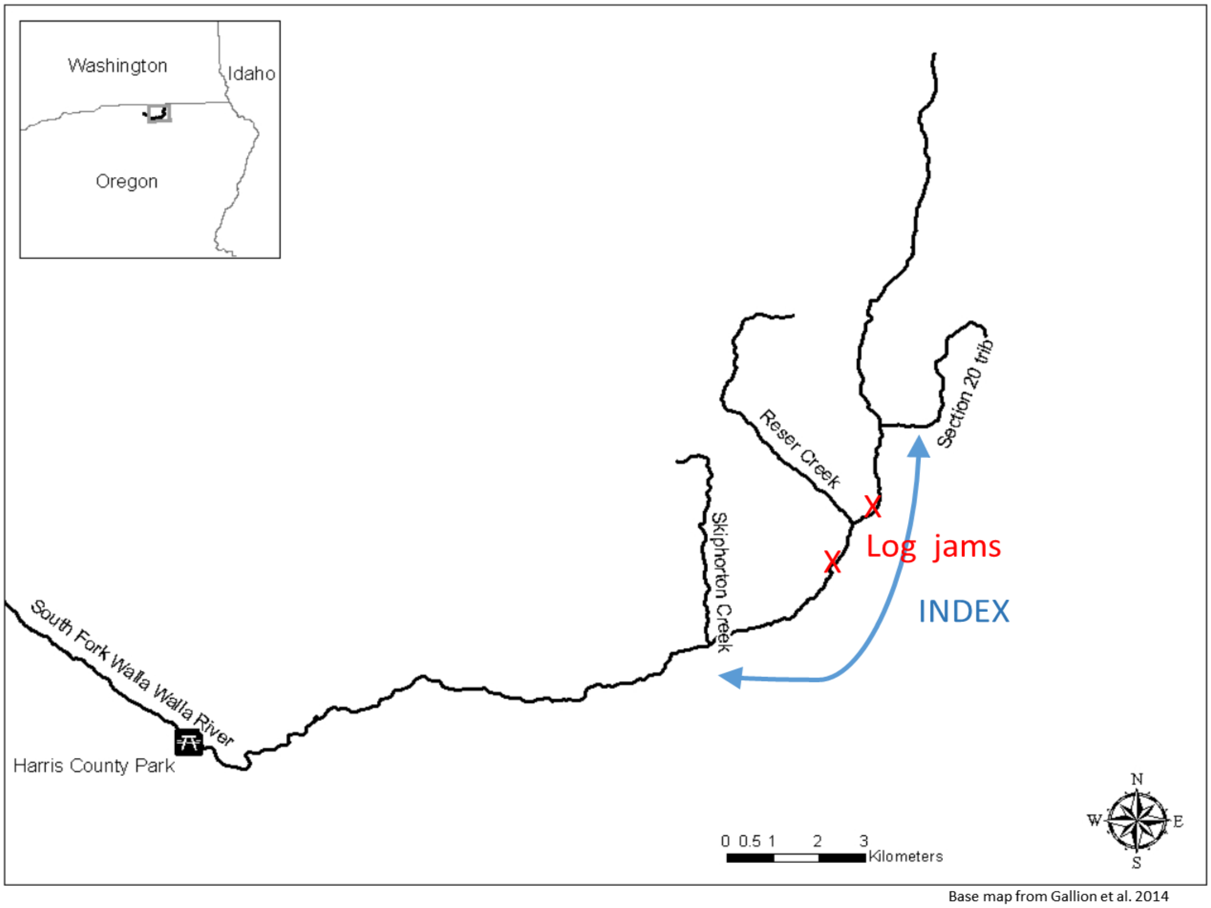



Figure 22. Location of log jams and spawning survey index reaches in the South Fork Walla Walla River.

Figure 23. Log jam in the South Fork Walla Walla River (from Barrows et al. 2014).

In addition, there are inconsistencies in the patterns of the redd counts and the video counts at Nursery Bridge Dam (Figure 24). Nursery Bridge Dam is located approximately 27 km downstream of Harris Park, which is the recognized lower limit of the bull trout spawning area in the South Fork Walla Walla River. The video monitoring has been conducted during the period of upstream migration of fluvial adults, and the counts include only individuals >300 mm (i.e., adults).

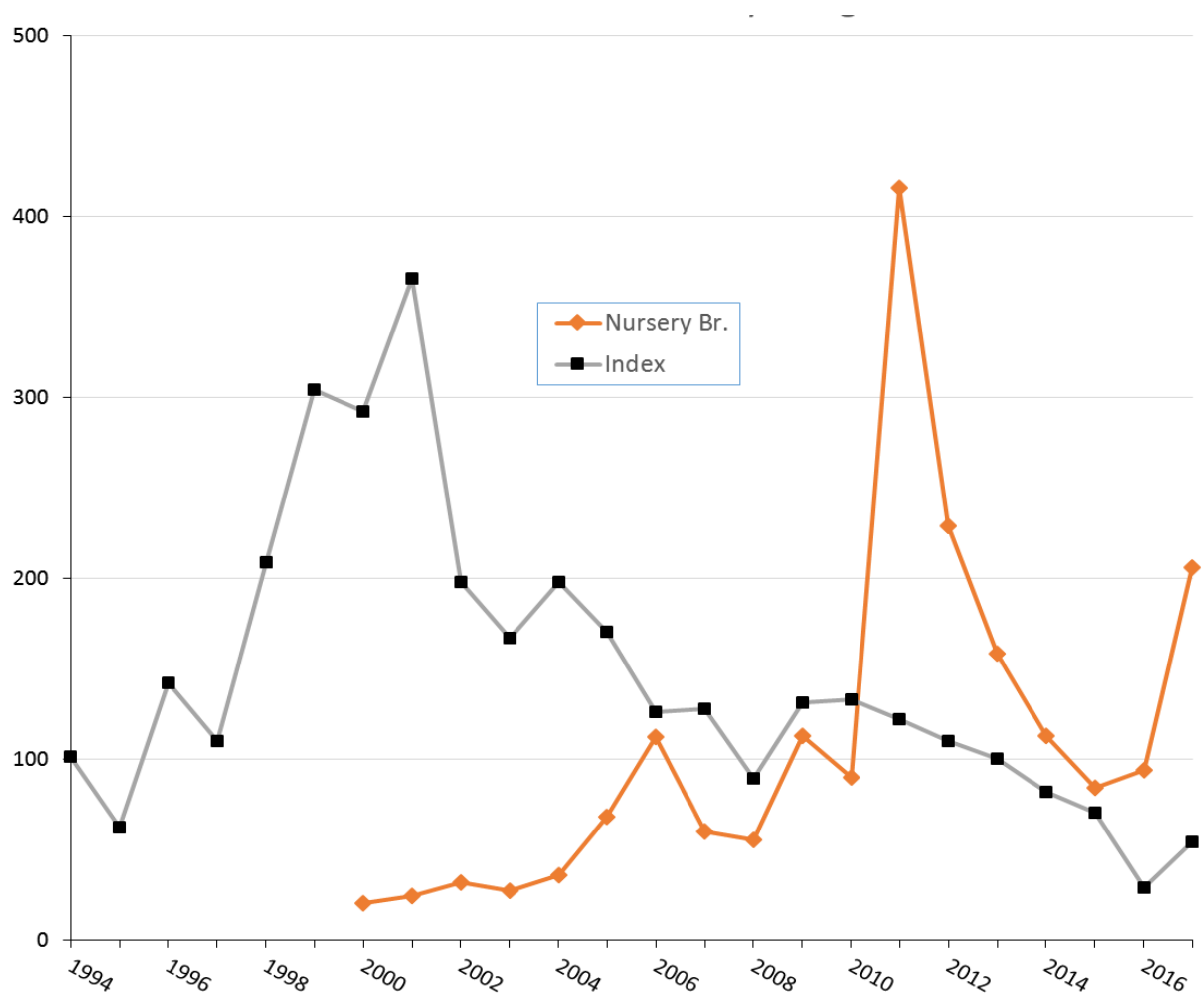



Figure 24. Index redd counts in the South Fork Walla Wall River vs. counts of adult bull trout at the Nursery Bridge Dam.

<u>Proposed South Fork Walla Walla Monitoring</u>

- Initially conduct extensive redd counts to define spawning distribution and possible effects of log jams and to determine future routine index survey reaches

- Conduct index redd surveys twice/season (approximately third week of September and third week of October)

This timing and frequency would account for about 97% of the spawning timing based on the six surveys conducted at 2 week intervals in 1991, 2001, and 2002.

- Measure redd length and size class of bull trout observed to determine migratory and resident components
- Continue Nursery Bridge Dam counts to supplement redd counts and track the fluvial population in the lower Walla Walla River
- Analyze genetic structure in Skiphorton and Reser creeks, which may contain resident populations, vs. the main stem South Fork Walla Walla population

*Umatilla Core Area*

Patch occupancy In the Umatilla core area was sampled by Sankovich and Anglin (2013). The only known population occurs in the North Fork Umatilla River, and it appears to be composed primarily of migratory life history forms. Brook trout distribution is limited to Meacham Creek.

Redd counts in the North Fork Umatilla River have generally been declining since 1999 (Figure 25). A census redd count in the early 2000s indicated that almost all of the redds in the North Fork were located in the index reach where the surveys are conducted. Bull trout have also been captured in the trap at Three Mile Falls Dam [river kilometer (Rkm) 6.4)]. Genetic analysis indicated that these fish were from populations outside of the Umatilla.

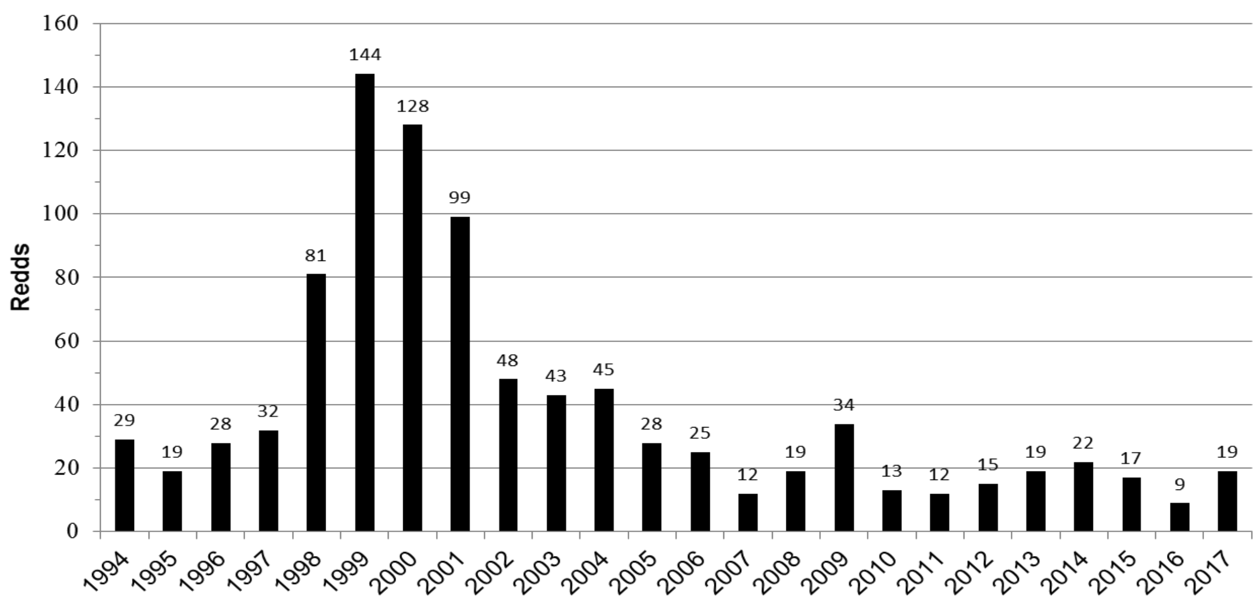



Figure 25. Redd counts for the North Fork Umatilla River, 1994-2017 (P. Sankovich, USFWS, unpublished data).

Proposed Umatilla Monitoring

- Continue annual redd counts in the North Fork Umatilla index reach 2 times/season (late September and mid-late October)

  Redd counts since 2007 have remained at low levels and warrant frequent monitoring.

- Measure redd length and size class of bull trout observed to determine migratory and resident components

- Conduct an extensive survey to revalidate the index reach

  The last extensive survey was done about 15-18 years ago.

- Continue to PIT-tag and collect tissue samples from bull trout trapped at Three Mile Falls Dam to monitor movements and for genetic analysis to identify their population of origin

*Upper Grande Ronde Core Area*

Information on the presence and distribution of bull trout is primarily based on past stream inventory data (Appendix figure 11), genetic sampling (Hemmingsen et al. 1996; Spruell et al. 2003), and more recent patch sampling. Meeuwig (ODFW, unpublished) sampled patch occupancy using electrofishing in 2018, but analysis of his results are not yet available. Adult abundance data is limited to some redd counts in small areas for a few years [North Fork Catherine Creek meadow (ODFW), South Fork Catherine Creek (USFS)]. Traps for upstream migrating fish on Catherine Creek and the upper mainstem Grande Ronde provide some information on the occurrence of fluvial adults (Table 11); however, very few are captured in the upper Grande Ronde.

Table 11. Captures of bull trout and lengths (mm) at the Catherine Creek and upper Grande Ronde weirs, 1999-2017 (CTUIR, unpublished data).

| | Catherine Creek Weir | | | | Upper Grande Ronde Weir | | | |
|---|---|---|---|---|---|---|---|---|
| | | Length | | | | Length | | |
| Year | Total | Mean | Min. | Max. | Total | Mean | Min. | Max. |
| 2002 | 3 | 353 | 273 | 405 | | | | |
| 2003 | 5 | 356 | 340 | 402 | | | | |
| 2004 | 7 | 354 | 305 | 430 | | | | |
| 2005 | 5 | 375 | 317 | 419 | | | | |
| 2006 | 1 | 527 | 527 | 527 | 2 | 436 | 435 | 436 |
| 2007 | 5 | 368 | 343 | 449 | | | | |
| 2008 | 4 | 353 | 316 | 428 | | | | |
| 2009 | 14 | 374 | 318 | 463 | | | | |
| 2010 | 31 | 376 | 311 | 490 | | | | |
| 2011 | 35 | 384 | 298 | 495 | | | | |
| 2012 | 56 | 388 | 315 | 550 | | | | |
| 2013 | 52 | 417 | 320 | 584 | 1 | 525 | 525 | 525 |
| 2014 | 33 | 459 | 303 | 610 | 3 | 427 | 365 | 505 |
| 2015 | 30 | 468 | 340 | 620 | 4 | 477 | 315 | 550 |
| 2016 | 23 | 469 | 330 | 637 | | | | |
| 2017 | 29 | 396 | 290 | 585 | | | | |

### Proposed Upper Grande Ronde Monitoring

- Sample eDNA in suitable unsampled or undersampled patches (see Appendix figure 11)

- Systematically electrofish or snorkel occupied patches to determine distribution and relative abundance of bull trout and brook trout

- Conduct future redd surveys where feasible based on distribution sampling, including measuring redd length and size class of bull trout observed

- Continue weir counts on Catherine Creek and upper Grande Ronde River to help monitor migratory forms

*Lookingglass/Wenaha Core Area*

### Lookingglass Creek Population

The population in Lookingglass Creek is suspected to be primarily a migratory population based on adult fish captured in the upstream trap at the weir at Lookingglass Hatchery, located downstream of the spawning distribution, but the potential proportion of resident forms is unknown. Data on adult abundance is available from redd counts and from counts from the weir operated in conjunction with Lookingglass Hatchery (Figure 26). The higher abundance estimates based on redd counts suggest that the redd counts provide more complete estimates of adult abundance. However, spawning surveys have decreased in frequency and occurrence in recent years due to decreases in available personnel.

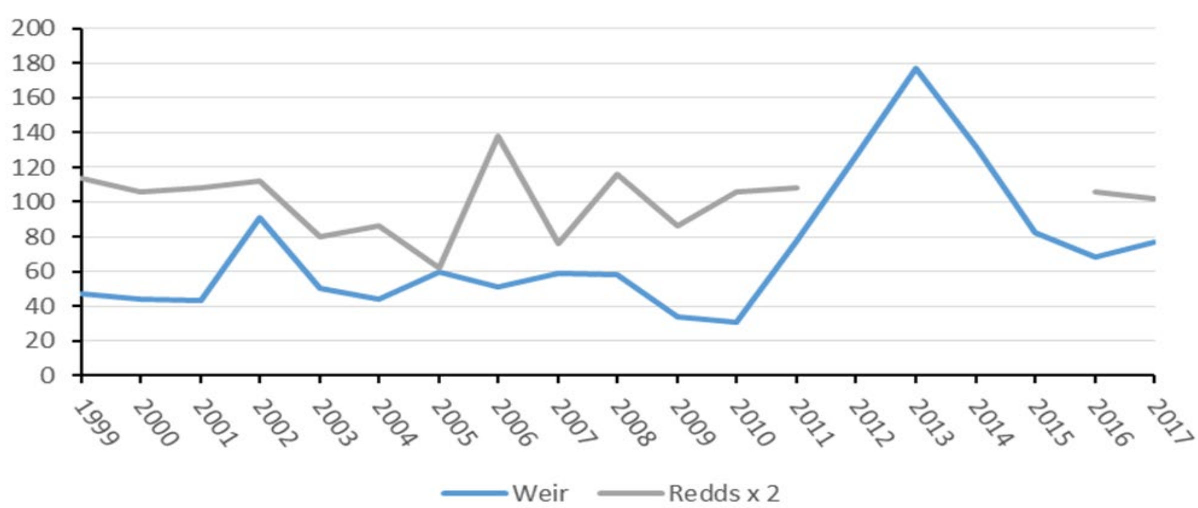



Figure 26. Counts of adults captured at the Lookingglass weir vs. estimates from redd counts [redd count x 2 adults/redd (Howell and Sankovich 2012)], 1999-2017.

Brook trout are found in Langdon Lake at the headwaters of Lookingglass Creek, and a few brook trout or hybrids have been documented in the screw trap catch in lower Lookingglass Creek (L. Naylor, CTUIR, pers. com.).

Proposed Lookingglass Creek Monitoring

- Continue redd counts (twice/season) in established survey reaches annually or biannually

Previously redd counts have been conducted as frequently as four times/season. That number could be reduced and still account for most of the redds (see previous discussion). Although annual counts would be preferable, counts every other year could reflect similar general abundance levels but with less precision over time (Figure 27).

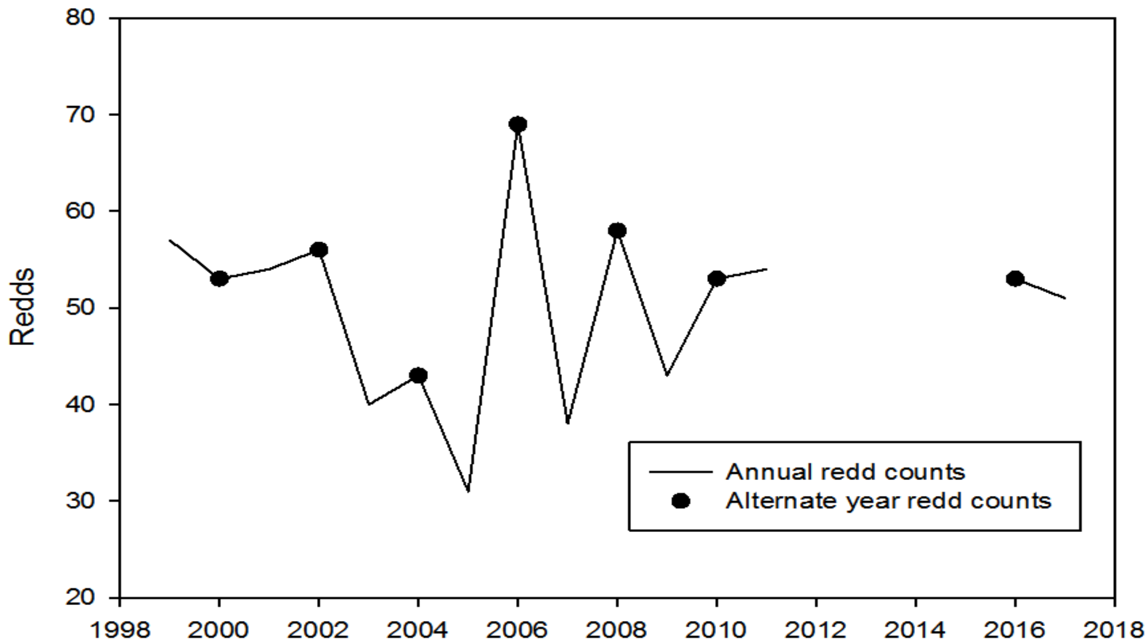



Figure 27. Annual vs. alternate year redd counts for Lookingglass Creek, 1999-2017.

- Measure redd length and size class of bull trout observed to determine migratory and resident components

- Continue weir counts to supplement redd counts

- Monitor weir and downstream traps for brook trout and hybrids

- Systematically electrofish or snorkel to determine distribution and relative abundance of brook trout and hybrids

Wenaha River Populations

Bull trout distribution and relative abundance in the main stem was estimated with a riverscape snorkel survey in 1998 and 1999 (Baxter 2002) (Figure 28). An extensive spawning survey, excluding the upper forks of Butte Creek, was conducted in 1996 (Buchanan et al. 1997) and in 2002. WDFW did a single redd count in West Fork Butte Creek in 2006. A telemetry study describes adult migration patterns (Starcevich et al. 2012). Those studies suggest the Wenaha population is relatively large and predominantly migratory, with the exception of a distinct possibly resident population in the upper North Fork (Figure 29). Genetic samples were collected by ODFW/FS (Spruell et al. 2002; P. Howell, 2002, 2004, unpublished data) and WDFW (Kassler and Mendel 2013). The primary spawning populations are in the North Fork and South Fork Wenaha River and the East Fork and West Fork Butte creek. All of the spawning and juvenile rearing habitat is protected within a designated wilderness area.

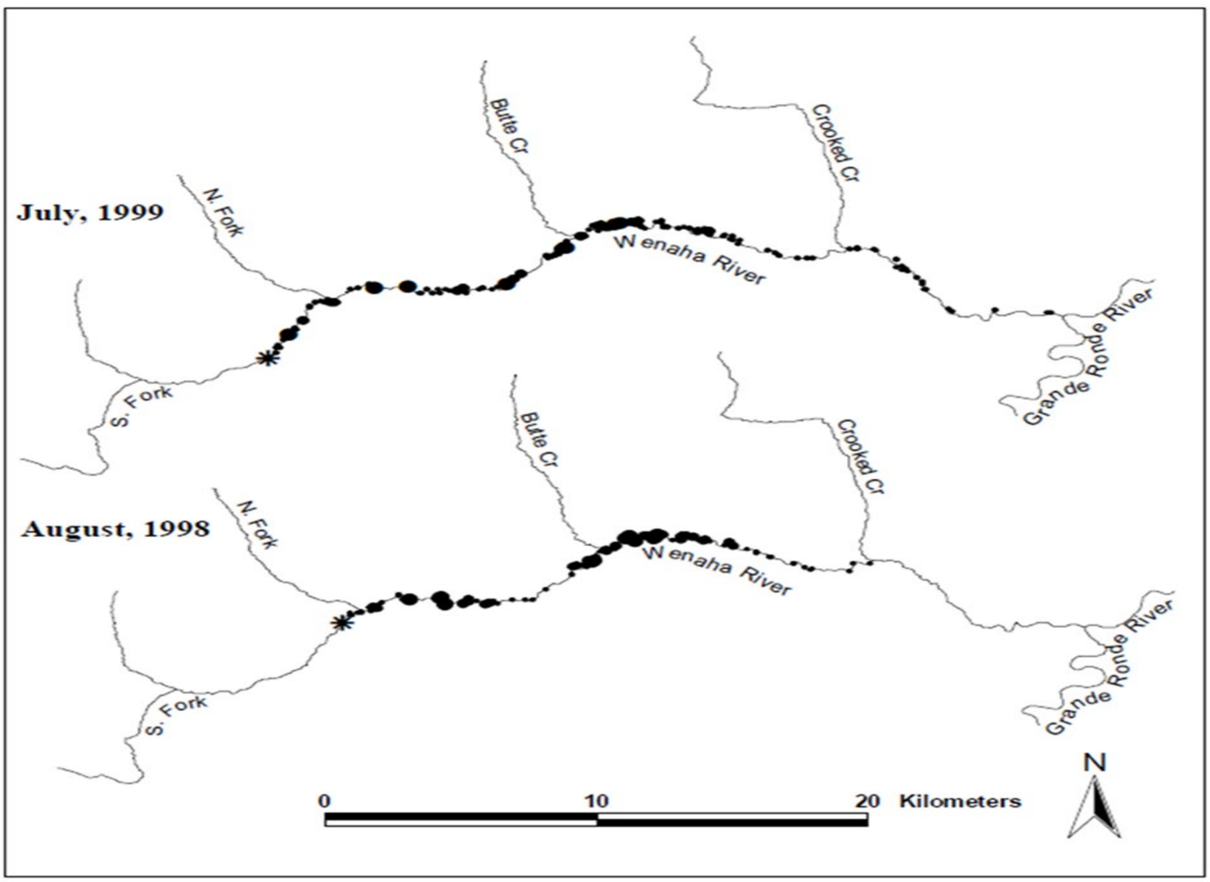



Figure 28. Abundance of adult bull trout from snorkel surveys in the Wenaha River, 1998-1999. Dot size indicates relative abundance. Asterisk indicates upstream limit of surveys (Baxter 2002).

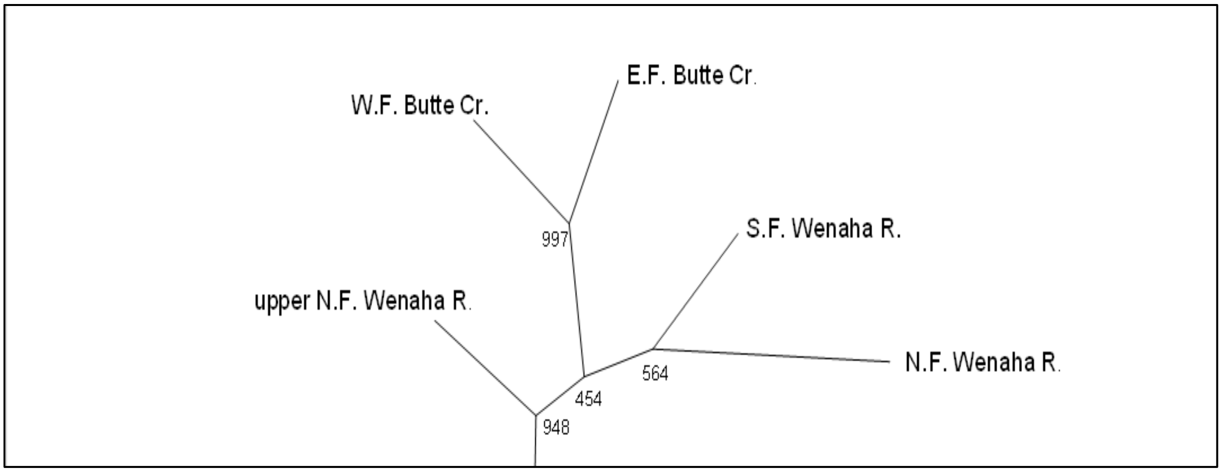



Figure 29. Genetic relationships among bull trout collections in the Wenaha River using Cavalli-Sforza and Edwards (1967) chord distance. Bootstrap values are shown at each node (Kassler and Mendel 2013).

Proposed Wenaha (S. Fork, lower N. Fork, main stem, Butte Creek) Monitoring

- Conduct a single, peak extensive redd count to identify index reaches

- Conduct periodic (5-10 years) single, "peak" redd counts in index reaches and after a major habitat change. If redd counts suggest a potentially substantial decline in the population, more frequent monitoring would be warranted.

  The extensive spawning distribution and remoteness make the logistics of spawning surveys challenging. The suspected relatively large size of the population and the low level of threats, particularly in the habitat within the wilderness area, do not suggest that more frequent monitoring is necessary.

- Measure redd length and size class of bull trout observed to determine migratory and resident components

- Conduct riverscape snorkel surveys at 10-year intervals to provide information on distribution and relative abundance of adults and juveniles/subadults.

  This would provide data for comparison with Baxter (2002). A snorkel survey of the main stem Wenaha River in mid-late summer would occur when most of the fluvial adults are staging in the main stem prior to moving into the tributaries to spawn (see also Starcevich et al. 2012).

- Sample presence/absence and distribution initially using eDNA in unsampled/undersampled portions of Crooked Creek (see Appendix figure 12).

  A spawning survey in 1996 documented redds in Crooked Creek from the mouth of Cherry Creek to Third Creek and in First and Third creeks (Buchanan et al. 1997). However, no bull trout were detected via electrofishing (P. Howell, unpublished data).

<u>Proposed Upper North Fork Wenaha Monitoring</u>

- Systematically electrofish or snorkel or conduct a single "peak" redd count to determine the distribution and relative abundance of the upper North Fork population at 10-year intervals

*Wallowa/Minam Core Area*

<u>Upper Wallowa Populations</u>

Spawning surveys have been conducted in reaches of Bear and Goat creeks since 1999 (Figure 30). Redd counts have generally ranged from 5 to 20, most of which were found in Goat Creek (Sausen 2018). Redd sizes suggest a mix of some fluvial and predominantly small resident-sized fish. The smaller redd sizes coupled with presence of brook trout make redd counts there difficult to interpret.

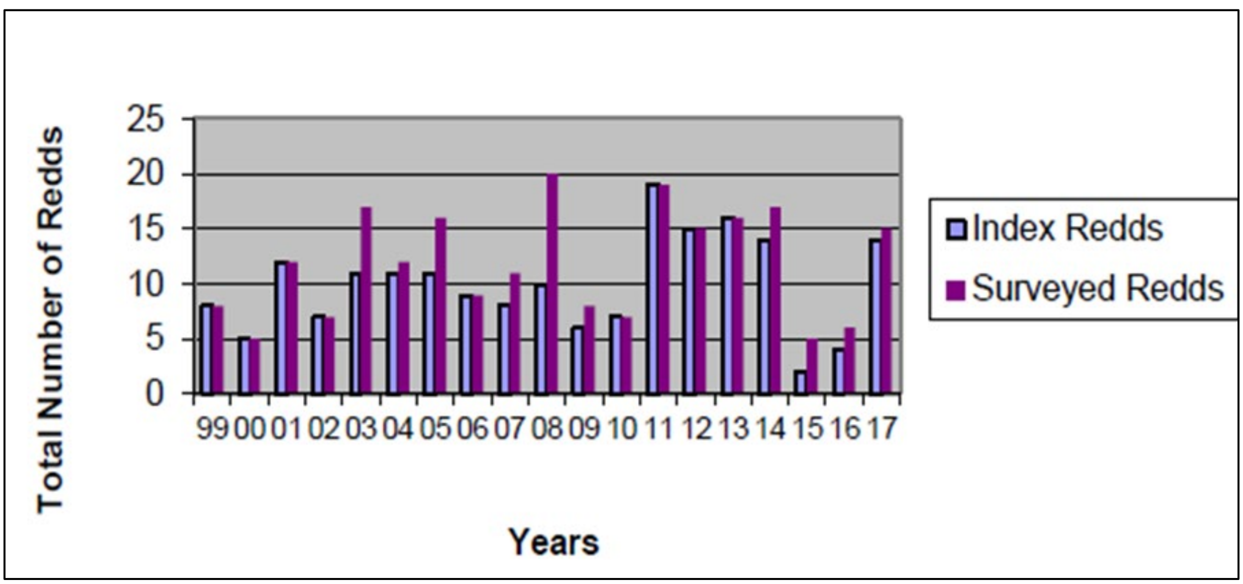



Figure 30. Bull trout redds in Bear and Goat creeks, 1999-2017 (Sausen 2018). Surveyed redds include all reaches surveyed in a given year.

Hurricane Creek appears to be predominantly brook trout with some hybrids and low numbers of bull trout based on genetic sampling in 1995 (Spruell et al. 2003) and 2003 (P. Howell, unpublished data).

A short 0.8 mi reach of Deer Creek has been periodically surveyed since 2009. Few redds have generally been observed (Table 12).

Table 12. Surveys and redd counts for Deer Creek, 2009-2017 (Sausen 2018).

| Year | Dates | Survey Frequency | Total Redds | Total Miles |
|---|---|---|---|---|
| 2009 | 10/14 | Once | 0 | 1.5 |
| 2010 | 9/17, 10/4 | Twice | 12 | 0.8 |
| 2011 | 9/19, 10/12 | Twice | 9 | 0.8 |
| 2012 | 9/21, 10/12 | Twice | 1 | 0.8 |
| 2013 | 9/23, 10/15 | Twice | 0 | 0.8 |
| 2016 | 9/21, 10/3 | Twice | 2 | 0.8 |
| 2017 | 9/21, 10/3 | Twice | 0 | 0.8 |

Spawning surveys have been conducted on the Lostine River since 1999.  Most of the redds occur in the upper Lostine from French Camp to Shady Falls (Sausen 2018). In addition, migratory adults are captured at the weir and trap near the mouth. The weir was reconstructed in 2010. Weir captures since then follow patterns more similar to redd counts; however, redd counts expanded by 2 fish/redd (Howell and Sankovich 2012) suggest redd counts account for a substantially higher proportion of the total population than do the weir captures. Brook trout are found in the upper Lostine, and underwater photos taken in 2010 and 2012 document hybrids, including large hybrids, and brook trout and hybrids paired with spawning bull trout (Sausen 2018). However, since the Lostine population is primarily a fluvial population (large redds created by large bull trout), redd counts in combination with large hybrids observed in the Lostine trap should still be a reliable representation of the composition of the spawning population.

Bull trout and brook trout distribution and relative abundance was sampled using electrofishing in the East Fork Wallowa River in 2012 and 2013 (Doyle 2014). One bull trout was also captured in BC Creek, a West Fork Wallowa tributary. The bull trout captured were also PIT-tagged. Genetic analysis indicated some of the fish were bull trout x brook trout hybrids. Large redds, likely from adfluvial fish, were observed in 2017 (J. Doyle, PacifiCorp, pers. com).

<u>Proposed Upper Wallowa Monitoring</u>

Hurricane, Bear and Goat creeks

- Systematically electrofish (or snorkel) to determine distribution and relative abundance of bull and brook trout and hybrids at 5-10 year intervals

Deer Creek

- Systematically electrofish to determine distribution and relative abundance of bull trout

Subsequently, future monitoring could consist of repeated systematic electrofishing surveys at 5-10 year intervals or redd surveys, if feasible.

Lostine River

- Continue annual redd counts (twice/season) in established survey reaches
- Measure redd length and size class of bull trout observed to determine migratory and resident components
- Continue weir counts and inspect fish captured for hybridization
- Systematically electrofish rearing habitat at 5-10 year intervals to determine brook trout distribution and estimate extent of hybridization

East Fork and West Fork Wallowa River

- Conduct electrofishing or snorkel surveys of bull trout, brook trout, and hybrid distribution and relative abundance every 5 years
- Continue annual redd counts in the East Fork Wallowa River and measure redd length

PacifiCorp has conducted annual redd counts in the East Fork Wallowa River and will continue to do so for the next 10 years as part of their FERC relicensing terms. However, because of the presence of brook trout, it is unclear whether those redds are created by bull trout or brook trout or both.  Large redds would be indicative of adfluvial bull trout from Wallowa Lake. The large numbers of kokanee spawning in the West Fork Wallowa River make bull trout spawning surveys there impractical.  Electrofishing surveys in the East Fork and snorkeling (or electrofishing where feasible) in the West Fork would enable monitoring of both bull trout, brook trout, and hybrids. Terms and conditions of PacifiCorp’s license also call for monitoring abundance, distribution, and life histories in both forks.

Minam River Populations

The Minam River was systematically snorkeled in 1996 (Appendix figure 13). Spawning surveys were also conducted in a reach near the mouth of Elk Creek in 2017 and 2018 (A. Miller, USFS, unpublished data). Brook trout occur in the upper Minam.  However there is substantial uncertainty concerning the extent of hybridization, spawning and rearing distribution, and life history composition (resident vs. fluvial forms). There are also a number of tributaries modelled as high probability for bull trout occurrence (Appendix figure 13) that have not been sampled. Suspected spawning and juvenile rearing habitat is protected within a designated wilderness area.

Proposed Minam River Monitoring

- Conduct initial riverscape or systematic snorkeling similar to that done in 1996

The large size and depth of the Minam River preclude the use of electrofishing. This would provide data for comparison with 1996, including distribution, size, life history forms, and hybridization.

- Sample eDNA in unsampled patches of tributaries identified as high probability for bull trout occurrence

Tributaries could be simultaneously eDNA sampled in conjunction with the snorkel sampling of the main stem.

- Conduct periodic (5-10 years) single, "peak" redd counts, if feasible, in reaches based on the snorkel survey or after major habitat change.

The remoteness and associated survey logistics do not make a second survey realistic.

- Measure redd length and size class of bull trout observed to determine migratory and resident components

*Little Minam River Core Area*

Census redd counts during 1998-2002 indicated a large, resident population (Figure 8). The population is wholly within designated wilderness, and no threats to the population were identified.

Proposed Little Minam River Monitoring

- Conduct redd counts twice/season at 8-10 year intervals and after a major habitat change. If redd counts suggest a potentially substantial decline in the population, more frequent monitoring would be warranted.

*Imnaha Core Area*

<u>Imnaha River and Cliff Creek Populations</u>

Spawning surveys have been conducted since 2001 in the Imnaha River, including Cliff Creek, an isolated resident population above a barrier falls (Sausen 2018). Because of the remoteness and logistics, the upper Imnaha and Cliff Creek were surveyed once/season. Fluvial migratory adults, which appear to predominate the spawning populations, except in Cliff Creek, migrate past the weir operated by ODFW at Rkm 87 near the downstream extent of bull trout spawning, some of which are captured in the trap and PIT-tagged. Using data from 2016 provides an example comparison of weir counts vs. redd counts as a measure of the adult population size. That year 371 adults were captured in the upstream trap and 108 redds were counted. If the redd count is multiplied by 2 adults/redd (Howell and Sankovich 2012), the redd count accounts for 216 adults. The efficiency of the weir trap for that year was estimated to be about 40 percent (Paul Sankovich, pers. com.). Consequently, the expanded weir count that incorporates that efficiency would be 594 adults, suggesting that the Imnaha is one of the largest fluvial populations in this region. Thus, the redd count only accounted for 36% of the fluvial population that migrated upstream of the weir, which is a conservative estimate of the total adult population since it doesn't include adults that do not migrate upstream of the weir.

<u>Proposed Imnaha River Monitoring</u>

- Continue weir counts
- Use PIT-tag detections to estimate weir efficiency

Because some migratory adults may remain up- or downstream of the weir trap site throughout the year, and others may move upstream past it before the weir is installed or by going through small openings designed into the weir, the trap count does not include the entire migratory adult population. The first step to estimate the number of migratory adults passing the weir would be to determine the ratio of marked (PIT-tagged)-to-unmarked migratory adults captured in the trap. This ratio would then be applied to estimate the number of unmarked migratory adults exhibiting these two behaviors: 1) marked migratory adults known (through their detections histories) to have passed the weir trap site before the weir was installed, and 2) marked migratory adults known to have passed the weir trap site via the openings in the weir. The estimated number of marked and unmarked migratory adults passing the weir trap site without being trapped would then be added to the trap count to obtain what would likely be a conservative estimate of migratory adult abundance. While there is no way to account for migratory adults remaining up- or downstream of the weir, the number of migratory adults moving upstream past the weir trap site before the weir is installed and passing through the weir openings can be estimated using data collected at the existing infrastructure (in-river PIT tag antennas just above and below the weir site and PIT tag detection capabilities at the trap).

- Use PIT-tag detections and weir recaptures to estimate adult-to-adult survival

  If a downstream trap becomes possible, it could also be used to estimate subadult-to-adult survival.

  Proposed Cliff Creek Monitoring

- Conduct a single, peak redd count in Cliff Creek at 8-10 year intervals and after a major habitat change

  Redd counts in Cliff Creek appear generally stable (i.e., no long-term decline) (Figure 31). The redd count reflects a single survey/year. That coupled with a substantial potential negative bias in resident redd counts (Howell and Sankovich 2012) suggests the adult population size could be considerably larger than represented by the redd count. Given the Cliff Creek population is in designated wilderness and faces few threats, more frequent redd counts do not appear necessary at this time. If redd counts suggest a potentially substantial decline in the population, more frequent monitoring would be warranted.

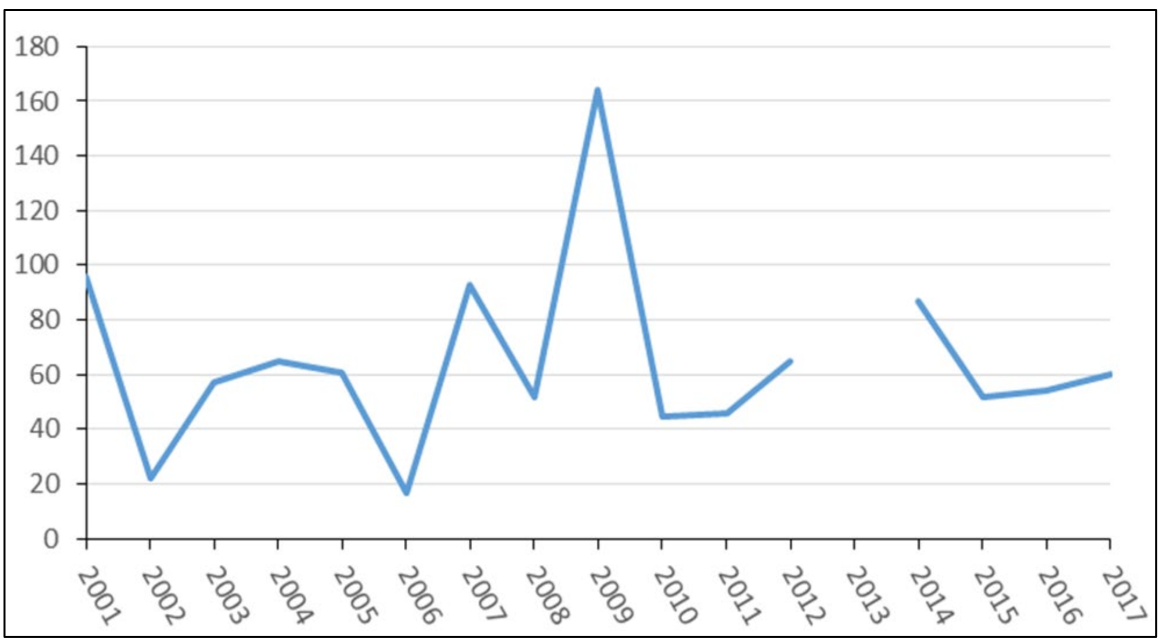



Figure 31. Redd counts in Cliff Creek, 2001-2017 (data from Sausen 2018).

Big Sheep, Lick, and McCully Creek Populations

Partial spawning surveys have been conducted on Big Sheep and Lick creeks since 2000 (Figure 32). Combined annual counts have generally ranged between 10 and 30 redds, suggesting small populations. Both populations have migratory fluvial and resident components (Hudson 2017). Redd counts provide demographic information via redd size to monitor both of those life history forms.

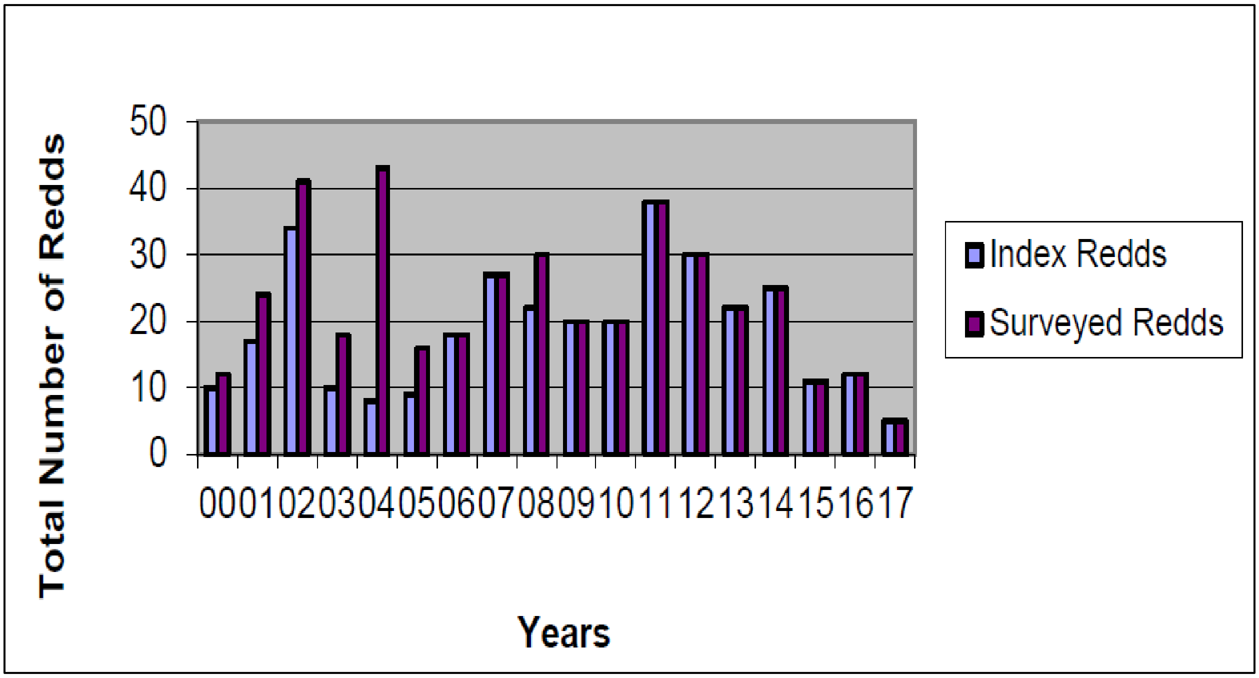



Figure 32. Index and total surveyed bull trout redds in Big Sheep Creek and Lick Creek, 2000-2017 (Sausen 2018).

Proposed Big Sheep, Lick, and McCully Creek Monitoring

- Continue redd counts in Big Sheep and Lick creeks. Compile counts of the two populations separately because of the high genetic population differentiation (Table 2)
- Extend survey reaches into upper Sheep Creek, where a substantial portion of the population occurs (Hudson 2017)
- Measure redd length and size class of bull trout observed to determine migratory and resident components

- Conduct electrofishing surveys of distribution and relative abundance in McCully Creek every 3-5 years

  McCully Creek contains a resident population. The habitat complexity (i.e., large amounts of woody debris) make spawning surveys unfeasible, whereas electrofishing sampling has been shown to provide estimates of population distribution and adult abundance (Hudson 2017).

Lower Imnaha Tributary Occupancy

Hudson et al. (2017) identified several potential bull trout patches in the lower Imnaha that they did not sample. Since then, 3 sites in the Horse Creek patch were sampled, but the results were negative (Appendix figure 15). R. Christian (pers. com.) also reported that bull trout occurred in Lightning Creek in the early 1990s, and also may have been trapped at weirs in Lightning, Cow, and Horse creeks. Three sections in lower Lightning Creek and one section in upper Lightning Creek were snorkeled in 1999. However, no bull trout were observed (USFS, unpublished).

Proposed Lower Imnaha Tributary Monitoring

- Sample eDNA for bull trout presence in patches identified as potential bull trout habitat that were not recently sampled or undersampled (e.g., Lightning and Cow creeks)

*Genetics—Upper Grande Ronde and Wallowa Core Areas*

Broadscale population structure of some populations was initially analyzed (Spruell et al. 2003; Ardren et al. 2011). Additional tissue samples were collected in 2002-2003 but not analyzed (P. Howell, unpublished data). Additional analysis of population and metapopulation structure would be helpful in identifying population units to monitor and understanding gene flow and connectivity among populations.

Proposed Genetics Monitoring

- Complete an analysis of population and metapopulation structure

## Appendix Tables

Appendix table 1. Monitoring attributes, methods, and primary existing sources of data for the Powder River and Pine Creek core areas. Published sources are cited in parentheses.

| Attribute (in priority) | Possible Methods | Existing information* |
|---|---|---|
| 1. Presence/absence/patch occupancy | eDNA | Eagle: USFS (Archuleta and Ratliff, undated), Pine-IP |
| | Electrofishing | ODFW, USFS, Pine: IPC 2013-2016 (Wilkison and Trainer 2017), Powder: 2013-2015 (Howell 2018), PBWC 2014 |
| | | (See also distribution) |
| | Snorkeling | |
| 2. Longitudinal distribution | | |
| a. Spawning/rearing/"resident" | Redd counts | Pine: ODFW 1998-2017 |
| | Electrofishing | Powder: 1996 (Bellerud et al. 1997), 2013-2015 (Howell 2018), PBWC 2014 |
| | | Pine: IPC 2013-2016 (Wilkison and Trainer 2017) |
| | Snorkeling | |
| | eDNA | See patch occupancy |
| b. Migratory | Traps | Pine:IPC 2012-2013 (Wilkison and Trainer 2017) |
| | Tagging | Pine: IPC 1998 (Wilkison and Trainer 2017) |
| | Snorkeling | |

| | | |
|---|---|---|
| 3. Life histories | See Distribution and Abundance | |
| Attribute (in priority) | Possible Methods | Existing information* |
| 4. Brook trout (presence, longitudinal distribution, relative abundance, hybridization) | eDNA | See patch occupancy |
| | Electrofishing | See distribution |
| | Snorkeling | |
| 5. Abundance (by life history type) | Redd counts | Pine: ODFW 1998-2017 |
| | Traps | |
| | Electrofishing | Powder: 1996 (Bellerud et al. 1997), 2013-2015 (Howell 2018), PBWC 2014<br>Pine: IPC 2013-2016 (Wilkison and Trainer 2017) |
| | Snorkeling | |
| | Mark-recapture | |
| 6. Genetics (structure, gene flow, abundance/Ne/b, bottlenecks, hybridization) | Electrofishing | ODFW/USFS research 1995 (Spruell et al. 2003)<br>Pine: hybridization—IPC (Wilkison and Trainer 2017) |
| | Traps | |
| 7. Vital rates (e.g., survival, productivity) | Mark-recapture | |

*U.S. Forest Service (USFS), Oregon Department of Fish and Wildlife (ODFW), Idaho Power Corporation (IPC), Powder Basin Watershed Council (PBWC)

Appendix table 2. Monitoring attributes, methods, and primary existing sources of data for the Malheur core areas. Published sources are cited in parentheses.

| Attribute | Possible Methods | Existing information* |
|---|---|---|
| 1. Presence/absence/patch occupancy | eDNA | |
| | Electrofishing | See below |
| | Snorkeling | |
| 2. Longitudinal distribution | | |
| a. Spawning/rearing/"resident" | Redd counts | ODFW-BPT 1992-2017 (Perkins 2013; Ramirez, 2017) |
| | Electrofishing | UM: ODFW 1982, 1989, 1993-94 (Bowers, unpublished), BPT (Schwabe et al. 2003; Schwabe et al. 2004 and other annual reports) |
| | Snorkeling | |
| | eDNA | |
| b. Migratory | Traps | NFM: Beulah (BOR 2015) |
| | | BPT (Schwabe et al. 2001 and following annual reports) |
| | Tagging | BPT (Schwabe et al. 2001 and following annual reports) |
| | Snorkeling | |
| 3. Life histories | See Distribution and Abundance | |

| Attribute | Possible Methods | Existing information* |
|---|---|---|
| 4. Brook trout | eDNA | |
| (presence, longitudinal distribution, relative abundance, hybridization) | Electrofishing | UM: ODFW 1982, 1989, 1993-94 (Bowers, unpublished), BPT (Schwabe et al. 2003; Schwabe et al. 2004 and other annual reports) |
| | Snorkeling | |
| 5. Abundance (by life history type) | Redd counts | ODFW-BPT 1992-2017 (Perkins 2013; Ramirez, 2017) |
| | Traps | |
| | Electrofishing | UM: BPT - (Schwabe et al. 2003 and other annual reports) |
| | Snorkeling | |
| | Mark-recapture | |
| 6. Genetics (structure, gene flow, abundance/$N_{e/b}$, bottlenecks, hybridization) | Electrofishing | Structure (DeHaan et al. 2007)<br>UM: Hybridization (DeHaan et al. 2009) |
| | Traps | |
| 7. Vital rates (e.g., survival, productivity) | Mark-recapture | |

* Upper Malheur (UM), North Fork Malheur (NFM), Oregon Department of Fish and Wildlife (ODFW), Burns Piute Tribe (BPT), Bureau of Reclamation (BOR)

Appendix table 3. Monitoring attributes, methods, and primary existing sources of data for the John Day core areas. Published sources are cited in parentheses.

| Attribute | Possible Methods | Existing information* |
|---|---|---|
| 1. Presence/absence/patch occupancy | eDNA | CTUIR, USFS |
| | Electrofishing | MFJD/Vinegar Cr.: 1999 ODFW et al.; 2016-2018 ODFW/Meeuwig |
| | Snorkeling | ODFW, USFS, CTUIR |
| 2. Longitudinal distribution | | |
| a. Spawning/rearing/"resident" | Redd counts | ODFW 2001-2017 |
| | | ODFW/USFS 2002-2005 (Moore et al. 2006) |
| | Electrofishing | NFJD: ODFW/USFS (Bellerud et al. 1997) |
| | Snorkeling | NFJD: USU (Budy et al. 2005; 2006); SF Desolation: USFS/ODFW |
| | eDNA | |
| b. Migratory | Traps | UJD: ODFW/USFS (traps, radio and PIT tags) (Hemmingsen et al. 2001a and following annual reports) |
| | | ODFW and FWS traps |
| | Tagging | |
| | Snorkeling | NFJD: USU (Budy et al. 2005; 2006); SF Desolation: USFS/ODFW |

| Attribute | Possible Methods | Existing information* |
| --- | --- | --- |
| 3. Life histories | | |
| 4. Brook trout | eDNA | CTUIR, USFS |
| (presence, longitudinal distribution, relative abundance, hybridization) | Electrofishing | NFJD- ODFW/USFS (Bellerud et al. 1997; Hemmingsen et al. 2001a) |
| | | UJD-ODFW Aquatic Inventory |
| | Snorkeling | NFJD- USU (Budy et al. 2006; 2007) |
| 5. Abundance (by life history type) | Redd counts | ODFW 2001-2017 |
| | | ODFW/USFS 2002-2005 (Moore et al. 2006) |
| | Traps | UJD-ODFW/USFS (Hemmingsen et al. 2001a and following annual reports) |
| | Electrofishing | MFJD-ODFW et al. 1999 |
| | Snorkeling | NFJD- USU (Budy et al. 2006; 2007), SF Desolation |
| | Mark-recapture | NFJD- USU (Budy et al. 2006; 2007) |
| 6. Genetics (structure, gene flow, abundance/$N_{e/b}$, bottlenecks, hybridization) | Electrofishing | ODFW/USFS 1995 (Spruell et al. 2003); 2002-3 samples collected, not analyzed |
| | | ODFW/Meeuwig |
| | Traps | |
| 7. Vital rates (e.g., survival, productivity) | Mark-recapture | |

*Upper John Day (UJD), Middle Fork John Day (MFJD), North Fork John Day (NFJD), U.S. Forest Service (USFS), Oregon Department of Fish and Wildlife (ODFW), Confederated Tribes of the Umatilla Indian Reservation (CTUIR), Utah State University (USU), .

Appendix table 4. Monitoring attributes, methods, and primary existing sources of data for the Walla Walla and Umatilla core areas. Published sources are cited in parentheses.

| Attribute | Possible Methods | Existing information* |
|---|---|---|
| 1. Presence/absence/patch occupancy | eDNA | |
| | Electrofishing | U: (Sankovich and Anglin 2013);ODFW/USFS |
| | Snorkeling | USFS |
| 2. Longitudinal distribution | | |
| a. Spawning/rearing/"resident" | Redd counts | WW/Mill: (Howell and Sankovich 2012), |
| | | SFWW and U: ODFW/USFWS 1994-2017 |
| | Electrofishing | WW/Mill: (Howell and Sankovich 2012) |
| | | SFWW: (Schaller et al. 2014 and related papers) |
| | Snorkeling | |
| | eDNA | |
| b. Migratory | Traps | Mill: (Howell et al. 2016) |
| | | Mill: Bennington dam counts-USACE |
| | | SFWW,WW: CTUIR |
| | | U: USFWS |
| | Tagging | WW/Mill: (Howell et al. 2016) |
| | | SFWW: (Schaller et al. 2014 and related papers) |
| | | WW/Mill and U: (Starcevich et al. 2012) |
| | Snorkeling | |

| Attribute | Possible Methods | Existing information |
|---|---|---|
| 3. Life histories | See Distribution and Abundance | |
| | Electrofishing | |
| | Snorkeling | SFWW: (Budy et al. 2009) |
| 5. Abundance (by life history type) | Redd counts | WW/Mill: (Howell and Sankovich 2012) |
| | | SFWW and U: ODFW/USFWS 1994-2017 |
| | Traps | WW/Mill: (Howell et al. 2016) |
| | Electrofishing | WW/Mill: (Howell and Sankovich 2012) |
| | Snorkeling | SFWW: (Budy et al. 2009) |
| | Mark-recapture | WW/Mill: (Howell and Sankovich 2012) |
| | | SFWW: (Schaller et al. 2014 and related papers) |
| 6. Genetics (structure, gene flow, abundance/Ne/b, bottlenecks, hybridization) | Electrofishing | ODFW/USFS 1995 (Spruell et al. 2003) |
| | | (Ardren et al. 2011) |
| | | WW/Mill/Low: Howell (unpublished) |
| | | SFWW: (Homel et al. 2008) |
| | Traps | |
| 7. Vital rates (e.g., survival, productivity) | Mark-recapture | WW/Mill: (Howell et al. 2016) |
| | | Growth: (Harris et al. 2018) |
| | | SFWW: (Schaller et al. 2014 and related papers) |

*Umatilla (U), Walla Walla (WW) U.S. Forest Service (USFS), Oregon Department of Fish and Wildlife (ODFW), Confederated Tribes of the Umatilla Indian Reservation (CTUIR), U.S. Fish and Wildlife Service (USFWS).

Appendix table 5. Monitoring attributes, methods, and primary existing sources of data for the Grande Ronde and Imnaha core areas. Published sources are cited in parentheses.

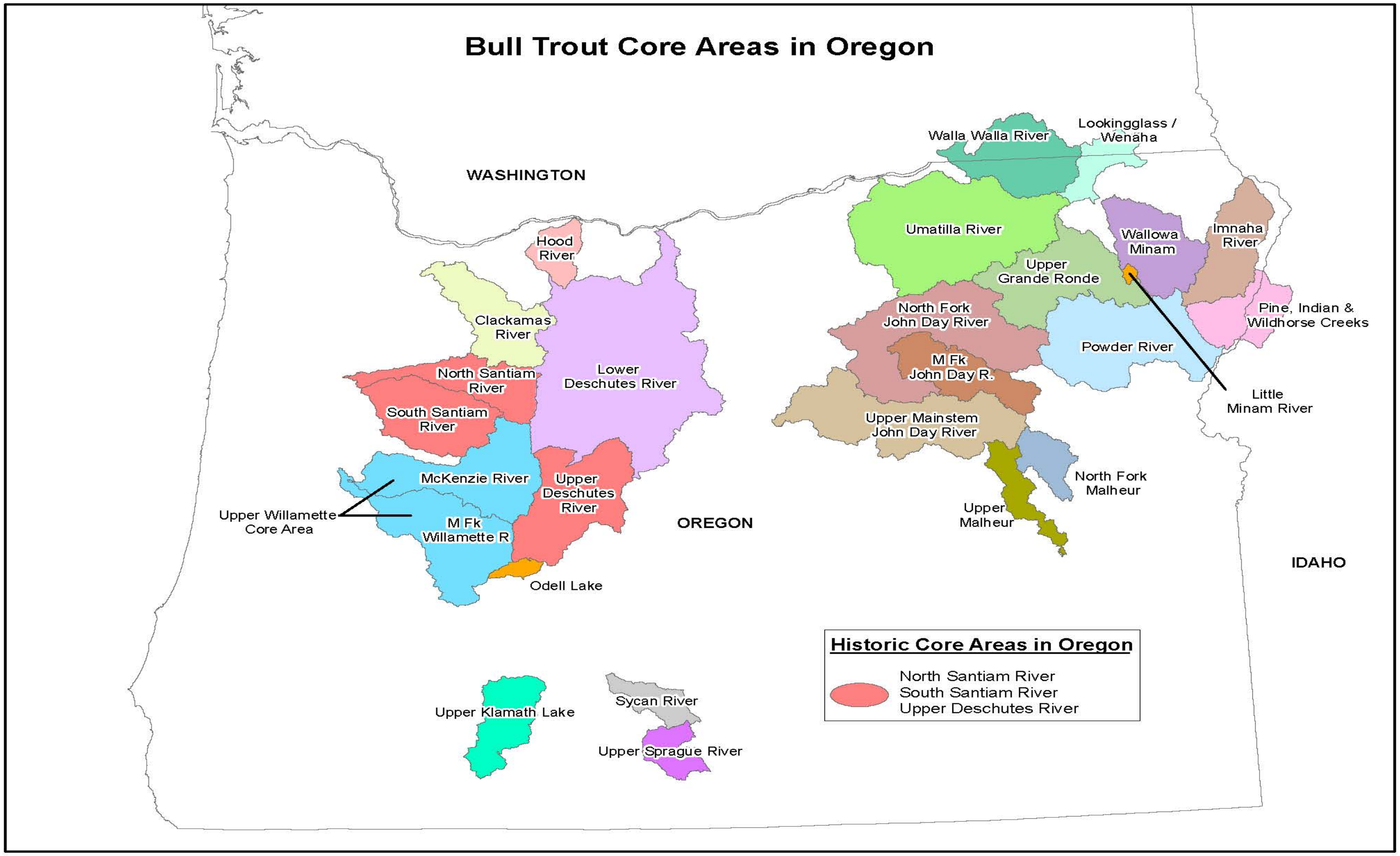
| Attribute | Possible Methods | Existing information* |
|---|---|---|
| 1. Presence/absence/patch occupancy | eDNA | USFWS, USFS (Archuleta and Ratliff, undated) |
| | Electrofishing | ODFW and USFS |
| | | UGR: ODFW/Meeuwig |
| | | Big Sheep, McCully, Lick crs.: (Hudson et al. 2017) |
| | Snorkeling | USFS |
| 2. Longitudinal distribution | | |
| a. Spawning/rearing/"resident" | Redd counts | Im, W/M: 1999-2017 (Sausen et al. 2018) |
| | | LM: (Hemmingsen et al. 2001a) |
| | | Lookingglass Cr.: USFS 1994-2017 |
| | Electrofishing | EF Wallowa (Doyle 2014) |
| | | NF Wenaha, Butte Cr.: WDFW 2006 |
| | Snorkeling | Wenaha (Baxter 2002) |
| | | Minam: ODFW |
| | eDNA | |
| | Traps | Lostine: NPT (upstream), ODFW (downstream) |
| b. Migratory | | Im: ODFW (upstream), NPT (downstream) |
| | | UGR: CTUIR (upstream), ODFW (downstream) |

| Attribute | Possible Methods | Existing information* |
|---|---|---|
| b. Migratory | Traps | Catherine Cr.: CTUIR (upstream), ODFW (downstream) |
| | | Lookingglass Cr.: ODFW (upstream), CTUIR (downstream) |
| | | Minam: ODFW (downstream) |
| | Tagging | Wenaha, Lostine, Imnaha: (Starcevich et al. 2012; Howell et al. 2010) |
| | | Im: (Chandler 2003) |
| | | EF Wallowa (Doyle 2014) |
| | Snorkeling | Wenaha (Baxter 2002) |
| | | Minam: ODFW |
| 3. Life histories | See Distribution and Abundance | |
| 4. Brook trout | eDNA | USFWS, USFS (Archuleta and Ratliff, undated) |
| (presence, longitudinal distribution, relative abundance, hybridization) | Electrofishing | ODFW and USFS |
| | | Hurricane Cr.(Hemmingsen et al. 2001a) |
| | Snorkeling | USFS |
| | | Minam: ODFW |
| 5. Abundance (by life history type) | Redd counts | Im, W/M: 1999-2017 (Sausen et al. 2018) |
| | | LM: 1997-2003 (Hemmingsen et al. 2001a) |
| | | Lookingglass Cr.: USFS 1994-2017 |
| | | NF Catherine Cr.: ODFW |
| | | SF Catherine Cr.: USFS |

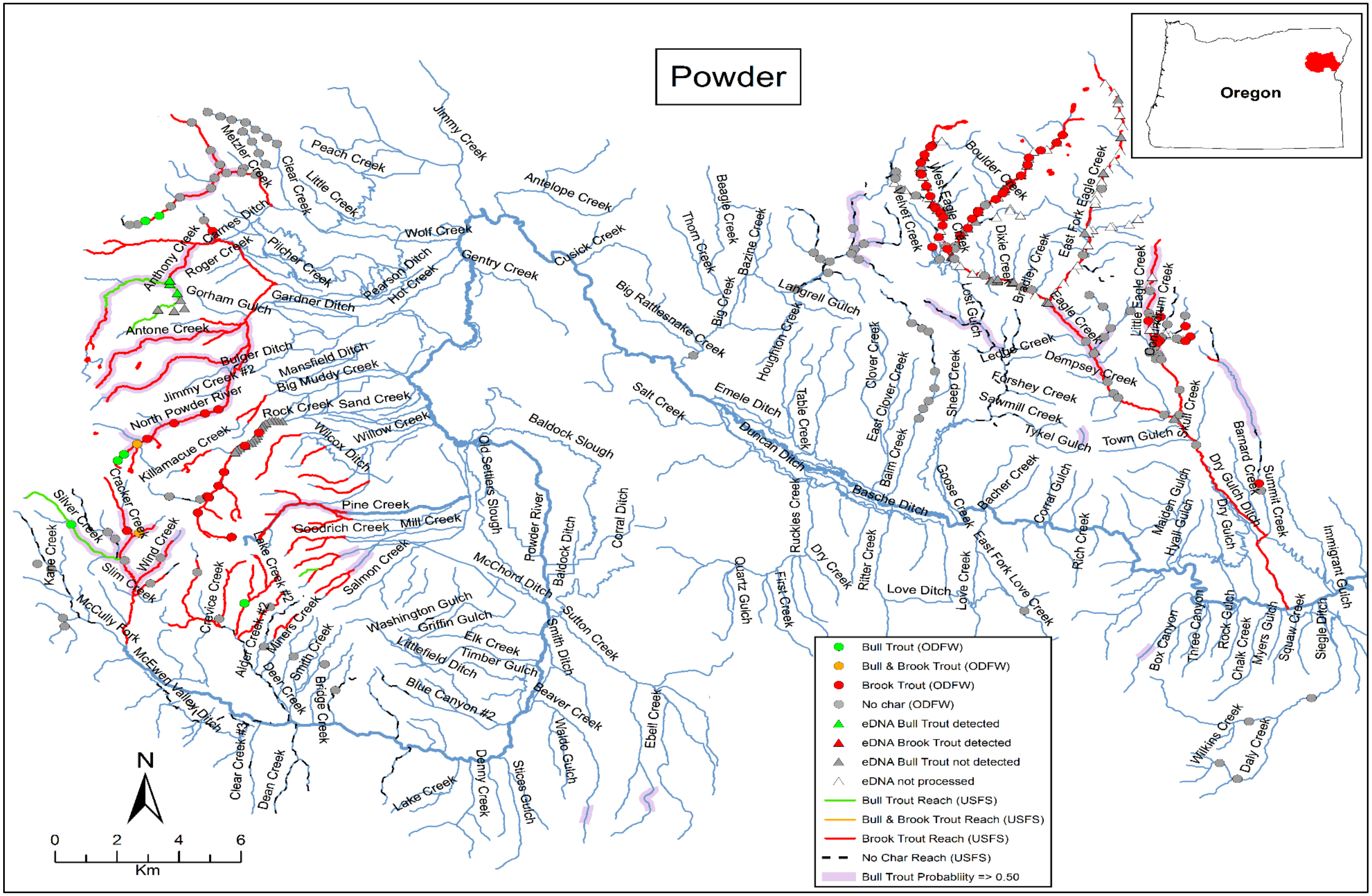
| Attribute | Possible Methods | Existing information* |
|---|---|---|
| 5. Abundance (by life history type) | Redd counts | Wenaha: ODFW 1996 (Buchanan et al. 1997); 2002 |
| | | NF Wenaha, Butte Cr. (Wenaha): WDFW 2006 |
| | | Minam: USFS 2017-2018 |
| | | EF Wallowa: (Doyle 2014) |
| | Traps | UGR, Catherine Cr., Lookingglass Cr.: CTUIR, ODFW |
| | | Lostine R.: NPT |
| | | Imnaha R.: ODFW |
| | Electrofishing | Big Sheep, McCully, Lick crs.: (Hudson et al. 2017) |
| | Snorkeling | Wenaha: (Baxter 2002) |
| | | Minam: ODFW |
| 6. Genetics (structure, gene flow, abundance/$N_{e/b}$, bottlenecks, hybridization) | Electrofishing | ODFW/USFS 1995 (Spruell et al. 2003); 2002-3 samples collected but not analyzed |
| | | Wallowa-Imnaha: (DeHaan et al. 2015) |
| | | Wenaha: (Kasler and Mendel 2013) |
| | | Big Sheep, McCully, Lick crs.: (Hudson et al. 2017) |
| | Traps | |
| 7. Vital rates (e.g., survival, productivity) | Mark-recapture | |

*Upper Grande Ronde (UGR), Wallowa/Minam (W/M), Little Minam (LM), Imnaha (Im), U.S. Forest Service (USFS), Oregon Department of Fish and Wildlife (ODFW), Confederated Tribes of the Umatilla Indian Reservation (CTUIR), Nez Perce Tribe (NPT), Washington Department of Fish and Wildlife (WDFW).

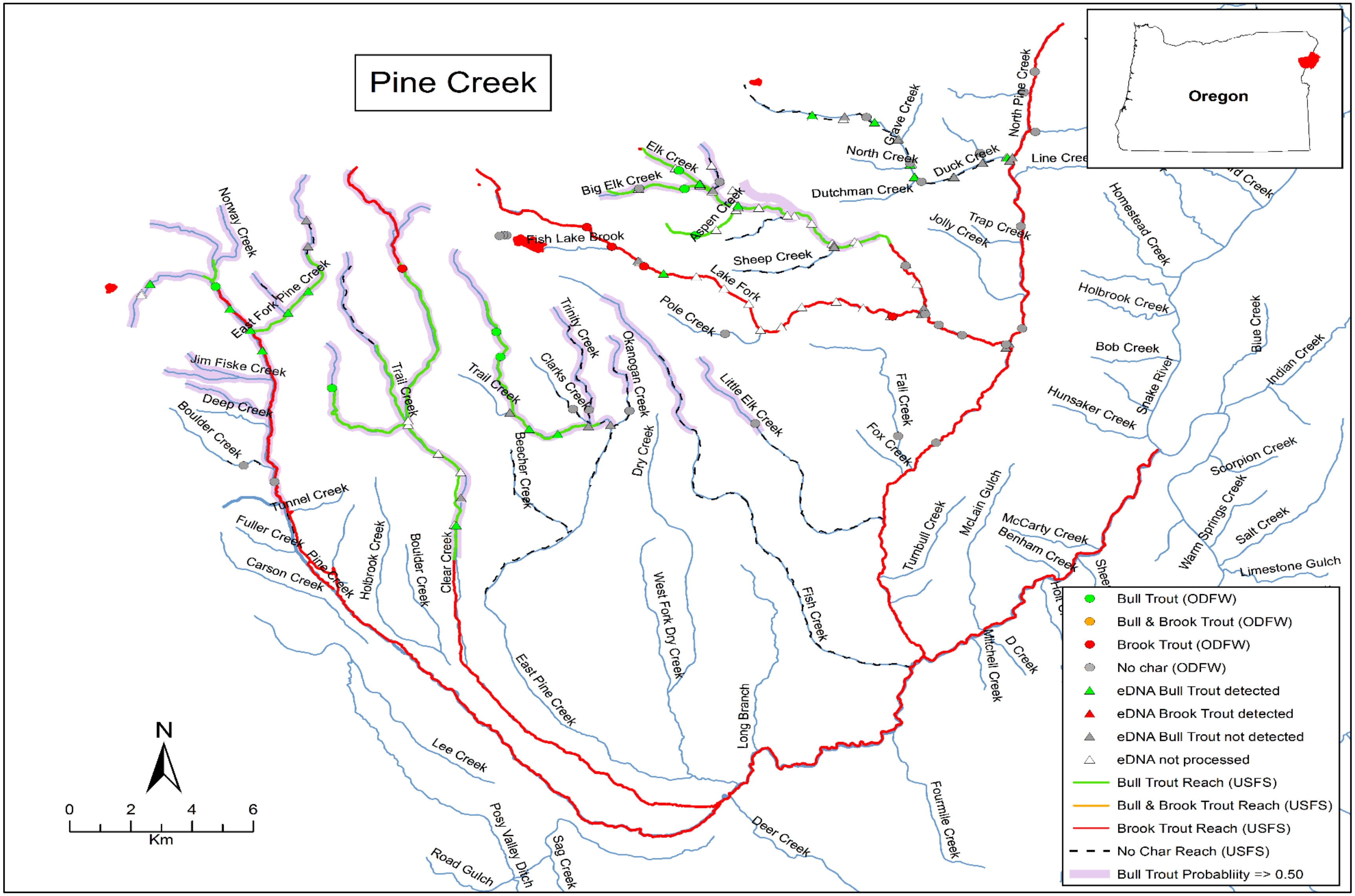
## Appendix Figures



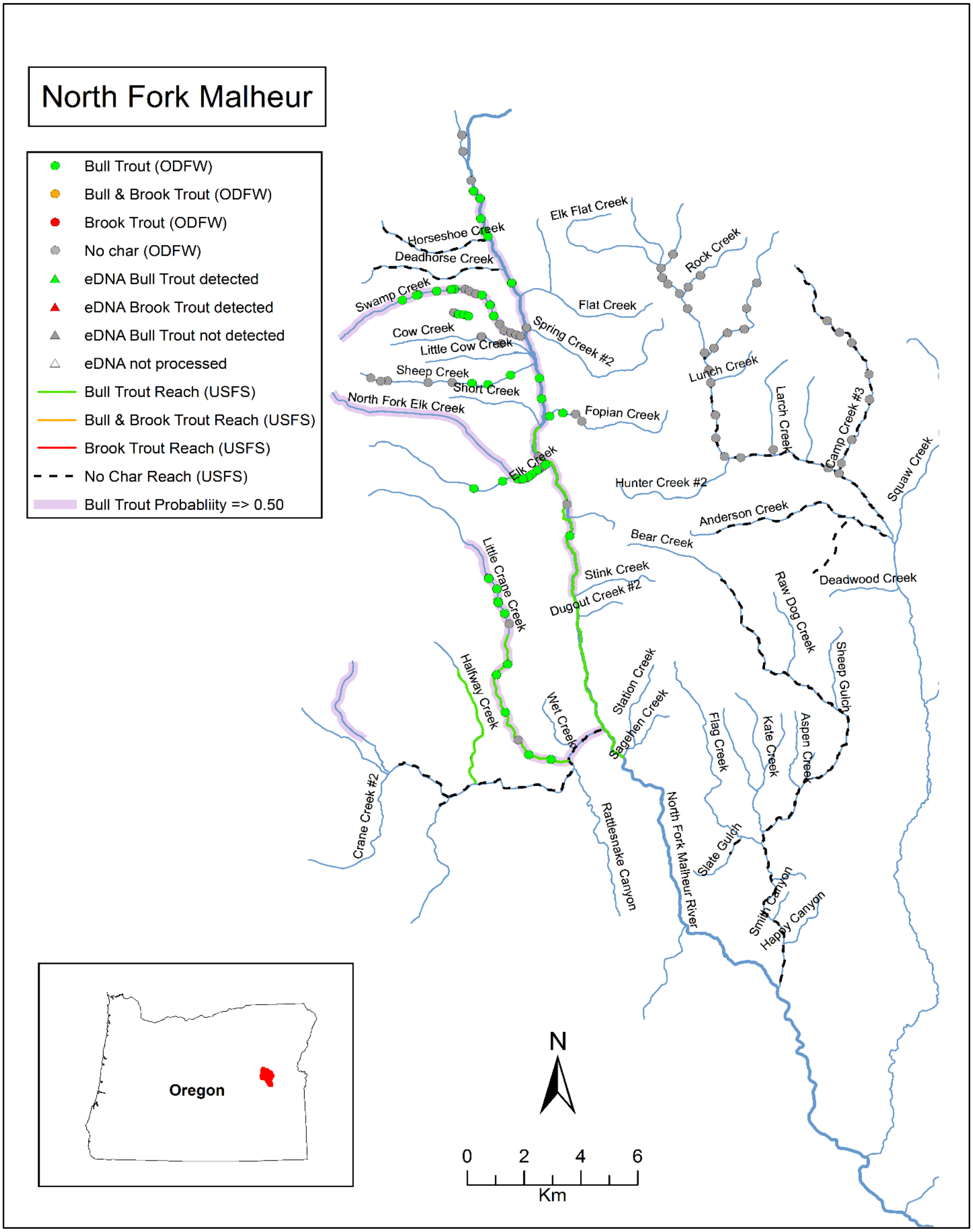

Appendix figure 1. Bull trout core areas in Oregon including those that overlap state boundaries into southeastern Washington. USFWS/OFWO generated map 2015.



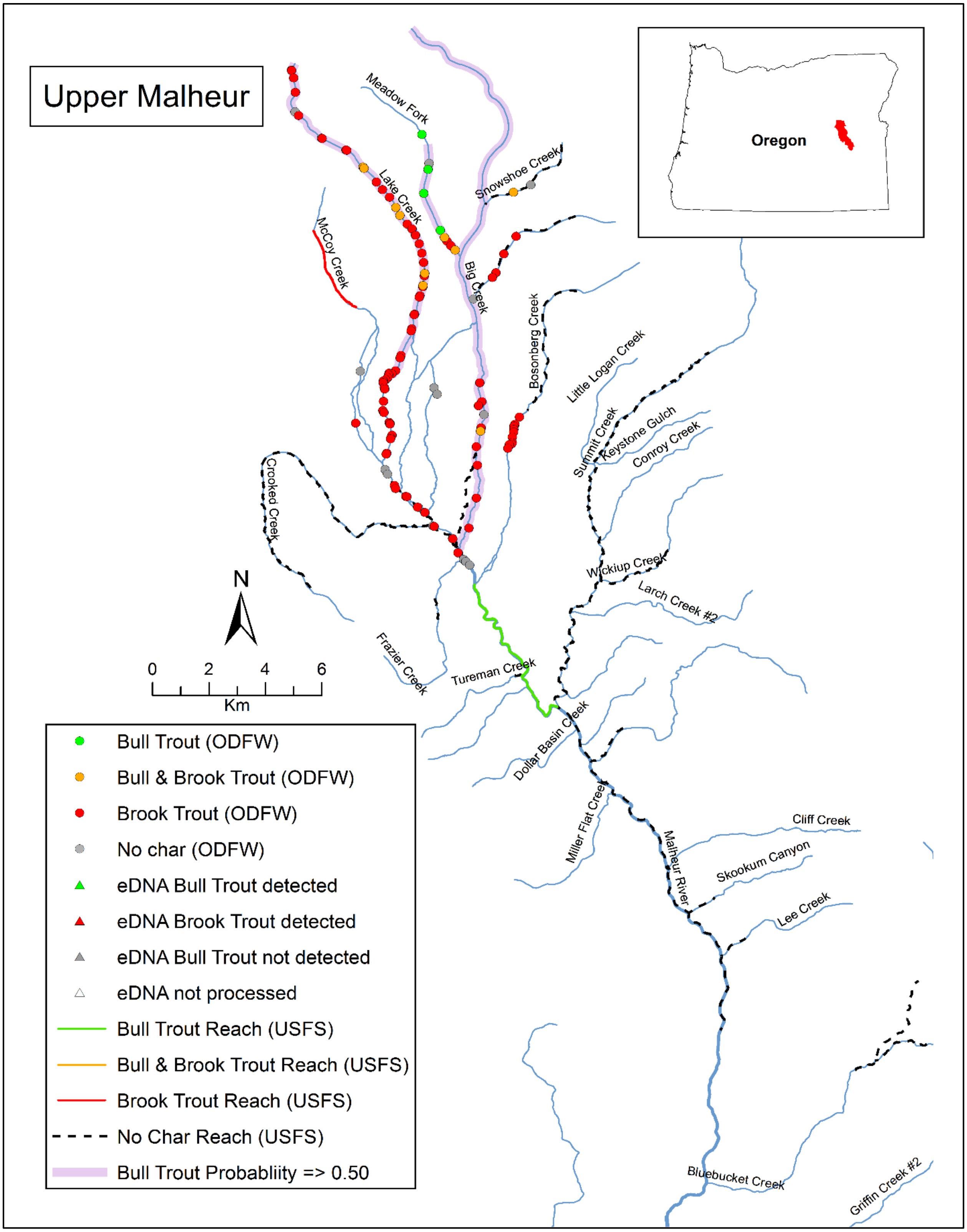

Appendix figure 2. Bull trout and brook trout occurrence and sample sites from ODFW aquatic inventories, USFS survey reaches, and eDNA sampling, and bull trout occurrence probability ≥0.50 (data from J. Dunham, USGS) in the Powder core area.



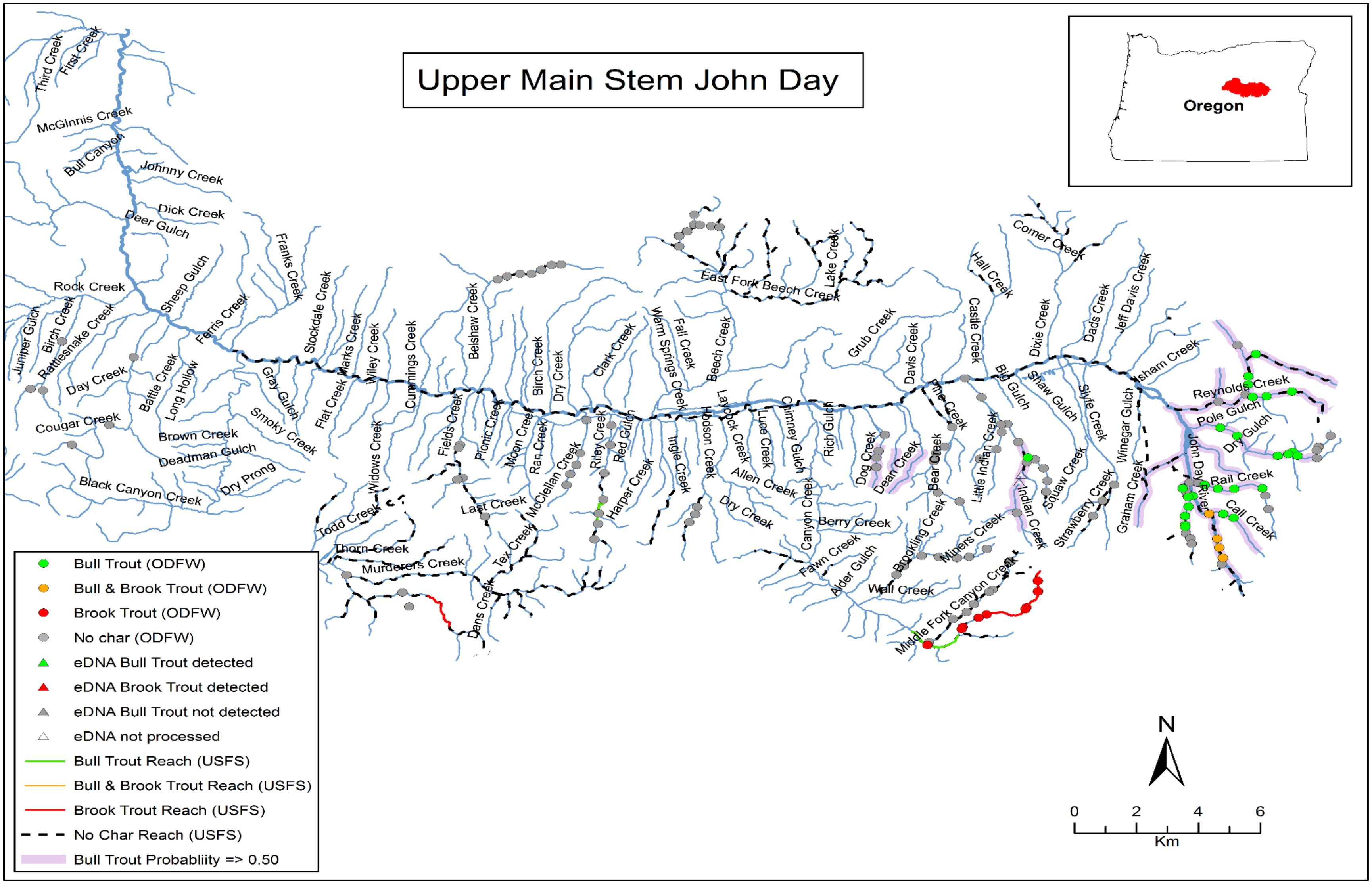

Appendix figure 3. Bull trout and brook trout occurrence and sample sites from ODFW aquatic inventories, USFS survey reaches, and eDNA sampling, and bull trout occurrence probability ≥0.50 (data from J. Dunham, USGS) in the Pine Creek core area.



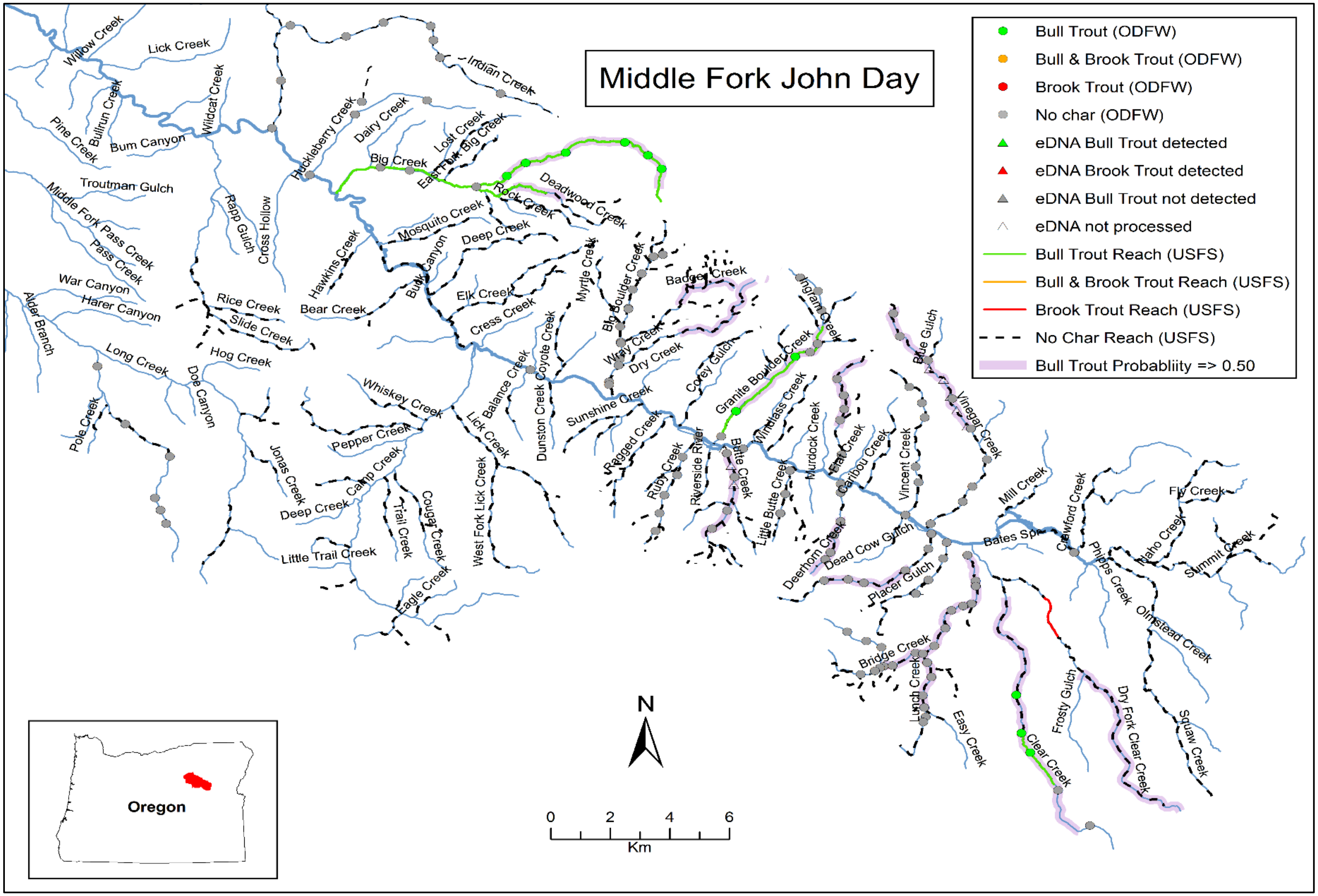

Appendix figure 4. Bull trout and brook trout occurrence and sample sites from ODFW aquatic inventories, USFS survey reaches, and eDNA sampling, and bull trout occurrence probability ≥0.50 (data from J. Dunham, USGS) in the North Fork Malheur core area.



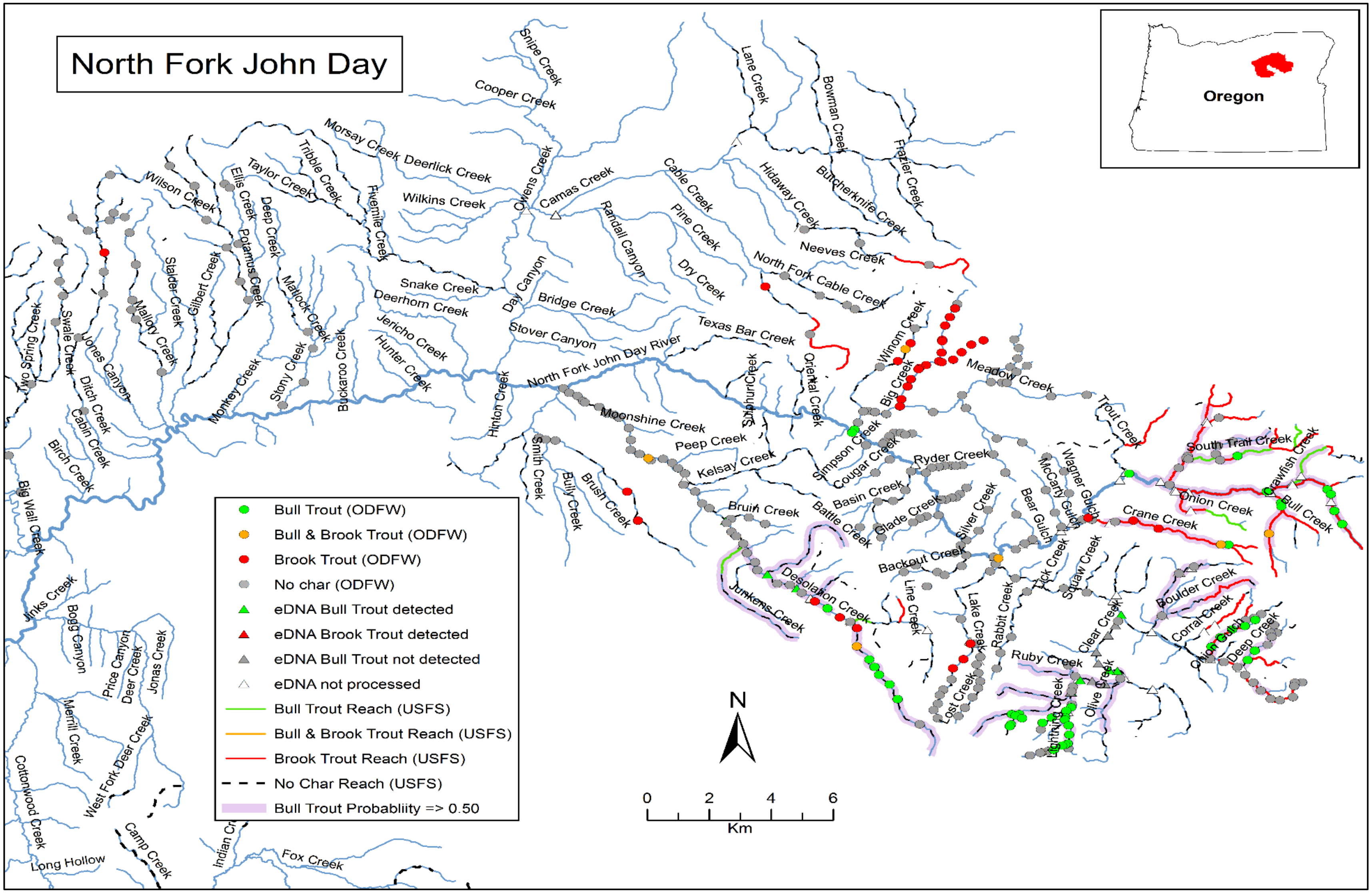

Appendix figure 5. Bull trout and brook trout occurrence and sample sites from ODFW aquatic inventories, USFS survey reaches, and eDNA sampling, and bull trout occurrence probability ≥0.50 (data from J. Dunham, USGS) in the Upper Malheur core area.



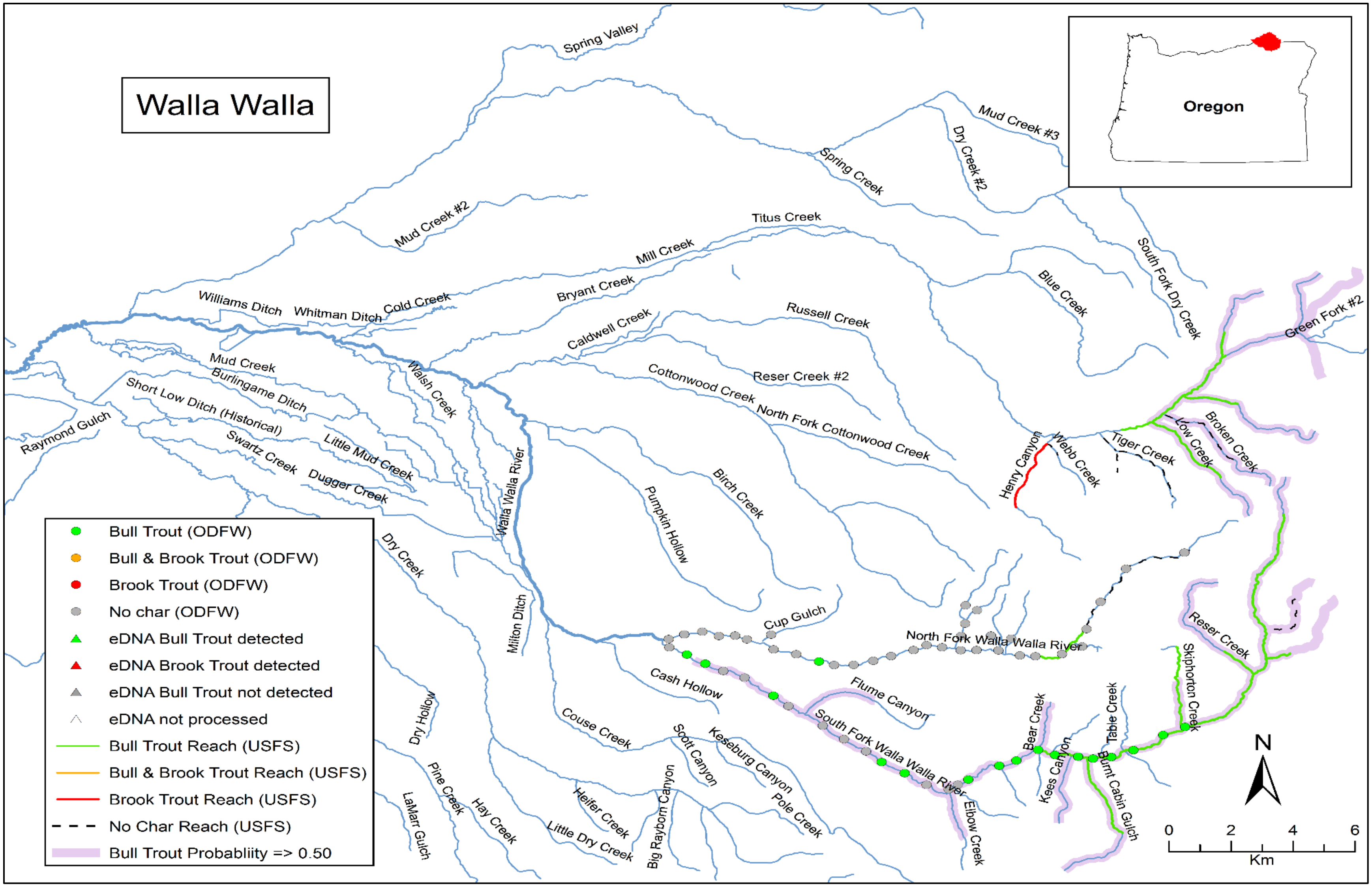

Appendix figure 6. Bull trout and brook trout occurrence and sample sites from ODFW aquatic inventories, USFS survey reaches, and eDNA sampling, and bull trout occurrence probability ≥0.50 (data from J. Dunham, USGS) in the Upper Main Stem John Day core area.



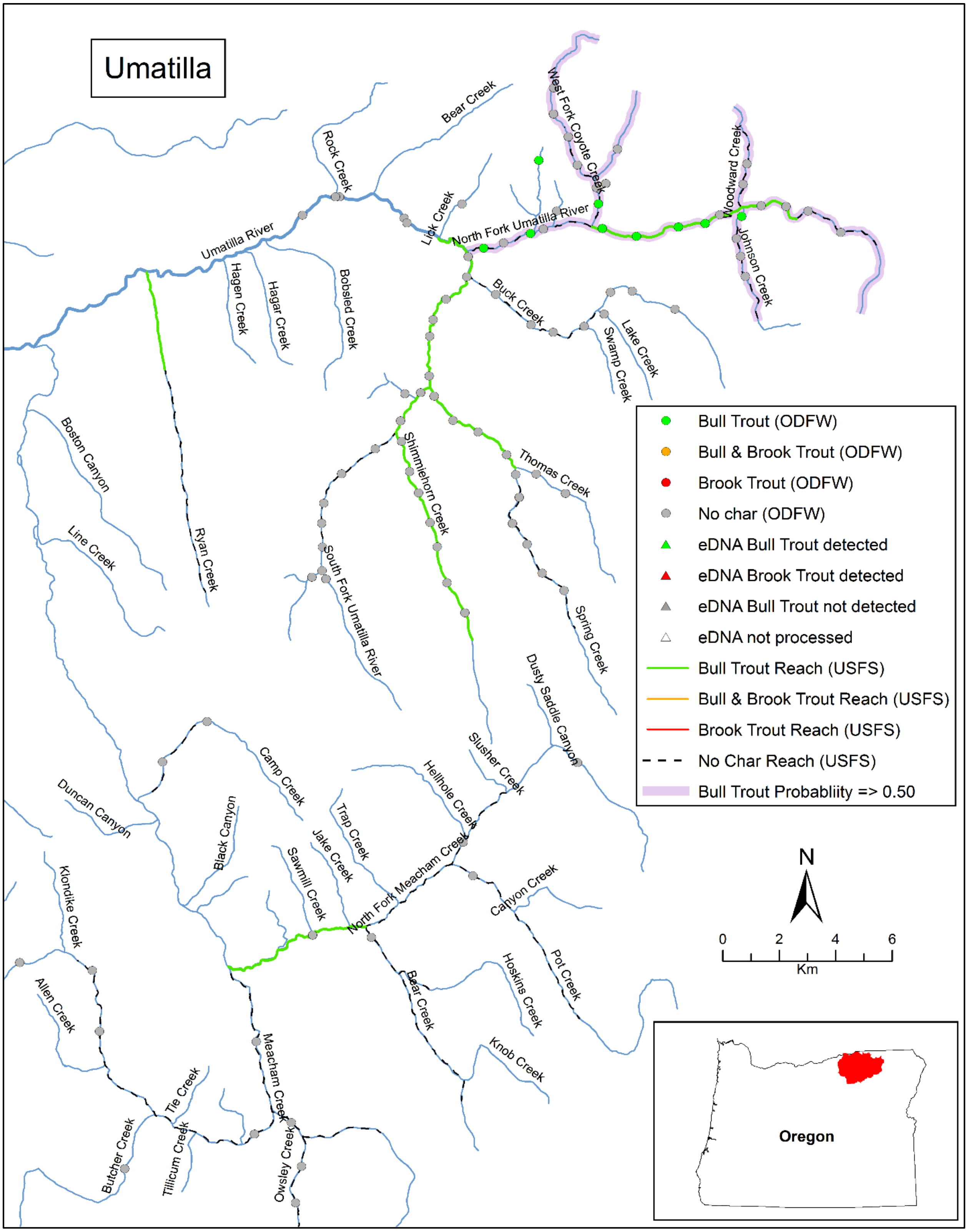

Appendix figure 7. Bull trout and brook trout occurrence and sample sites from ODFW aquatic inventories, USFS survey reaches, and eDNA sampling, and bull trout occurrence probability ≥0.50 (data from J. Dunham, USGS) in the Middle Fork John Day core area.



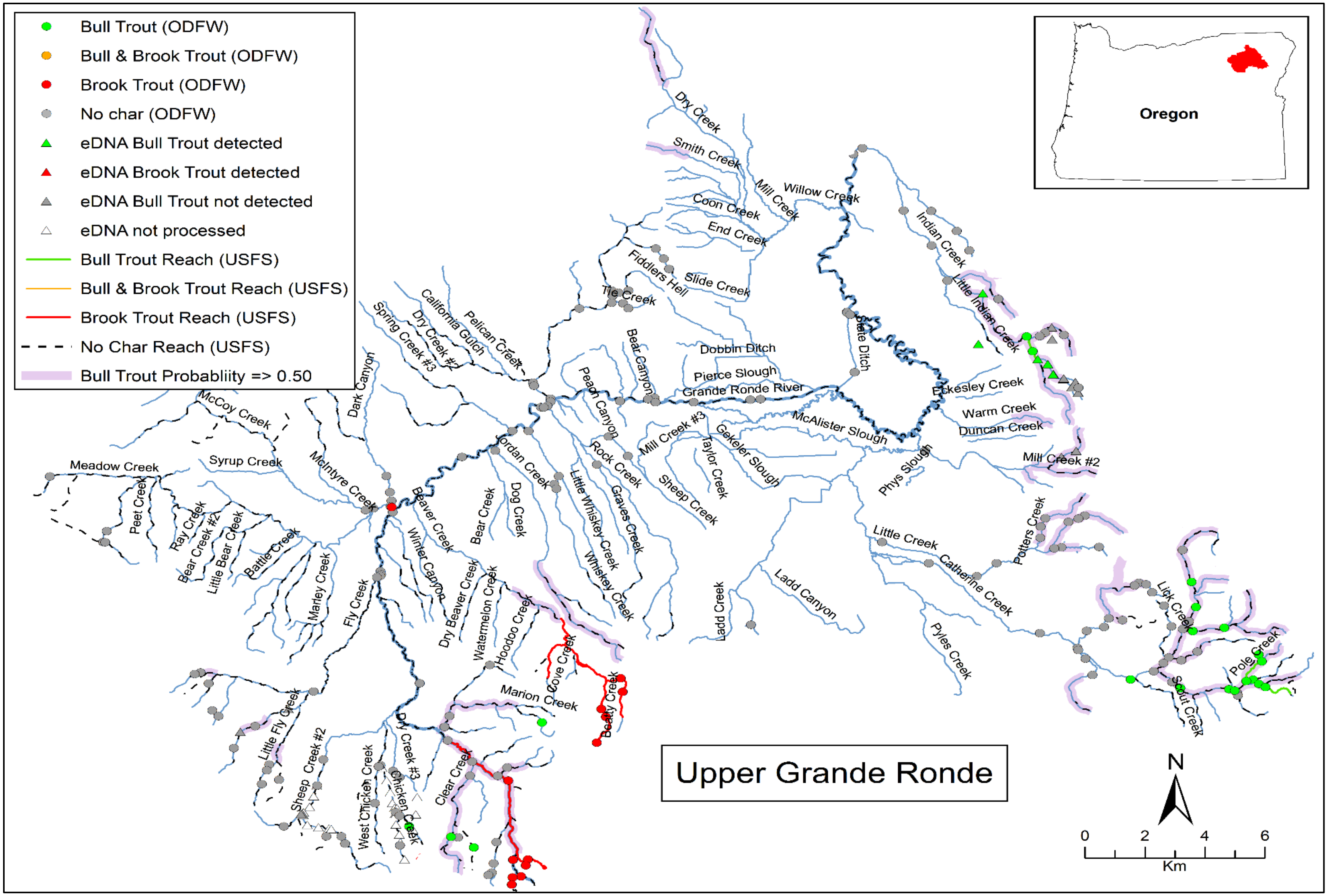

Appendix figure 8. Bull trout and brook trout occurrence and sample sites from ODFW aquatic inventories, USFS survey reaches, and eDNA sampling, and bull trout occurrence probability ≥0.50 (data from J. Dunham, USGS) in the North Fork John Day core area.



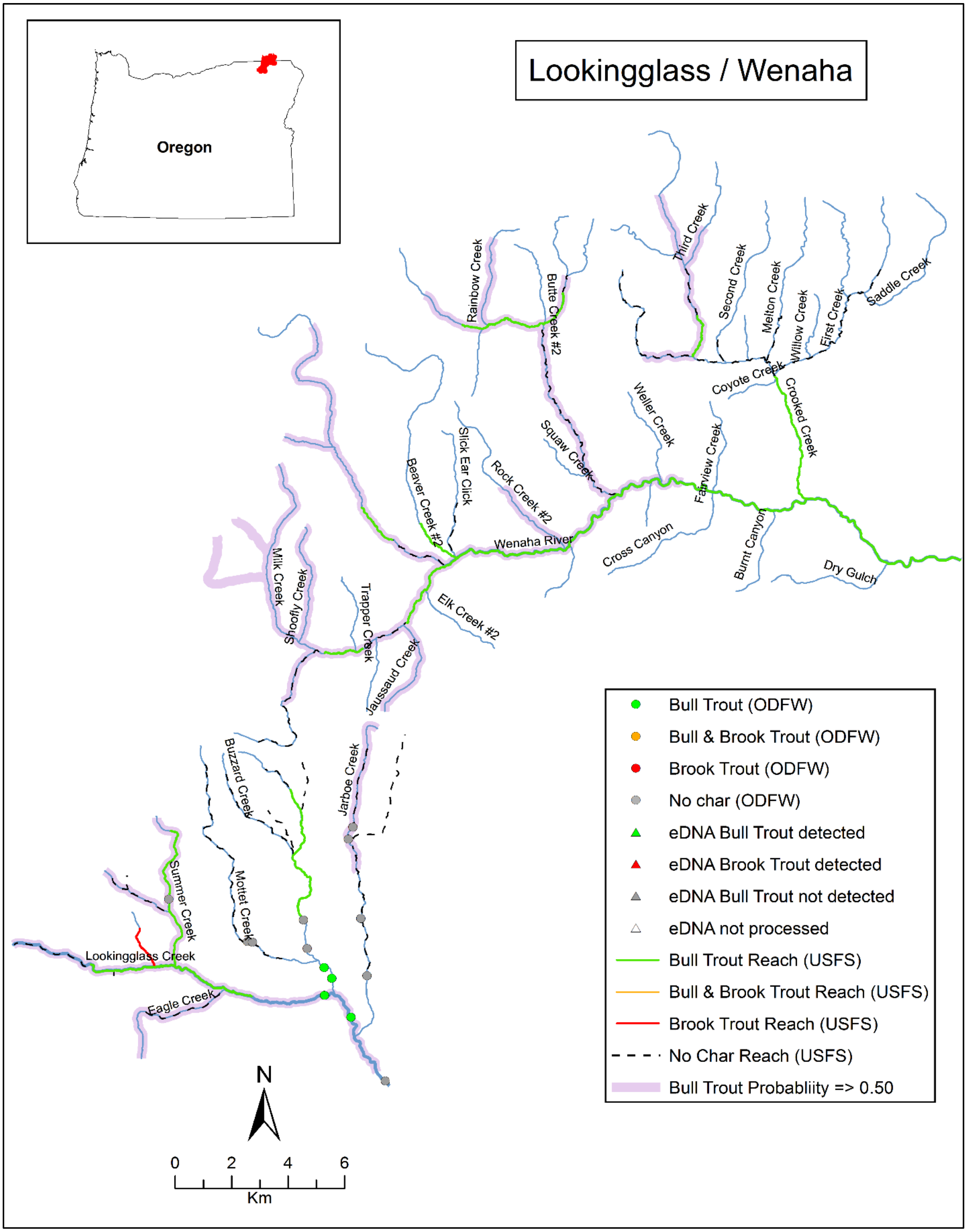

Appendix figure 9. Bull trout and brook trout occurrence and sample sites from ODFW aquatic inventories, USFS survey reaches, and eDNA sampling, and bull trout occurrence probability ≥0.50 (data from J. Dunham, USGS) in the Walla Walla core area.



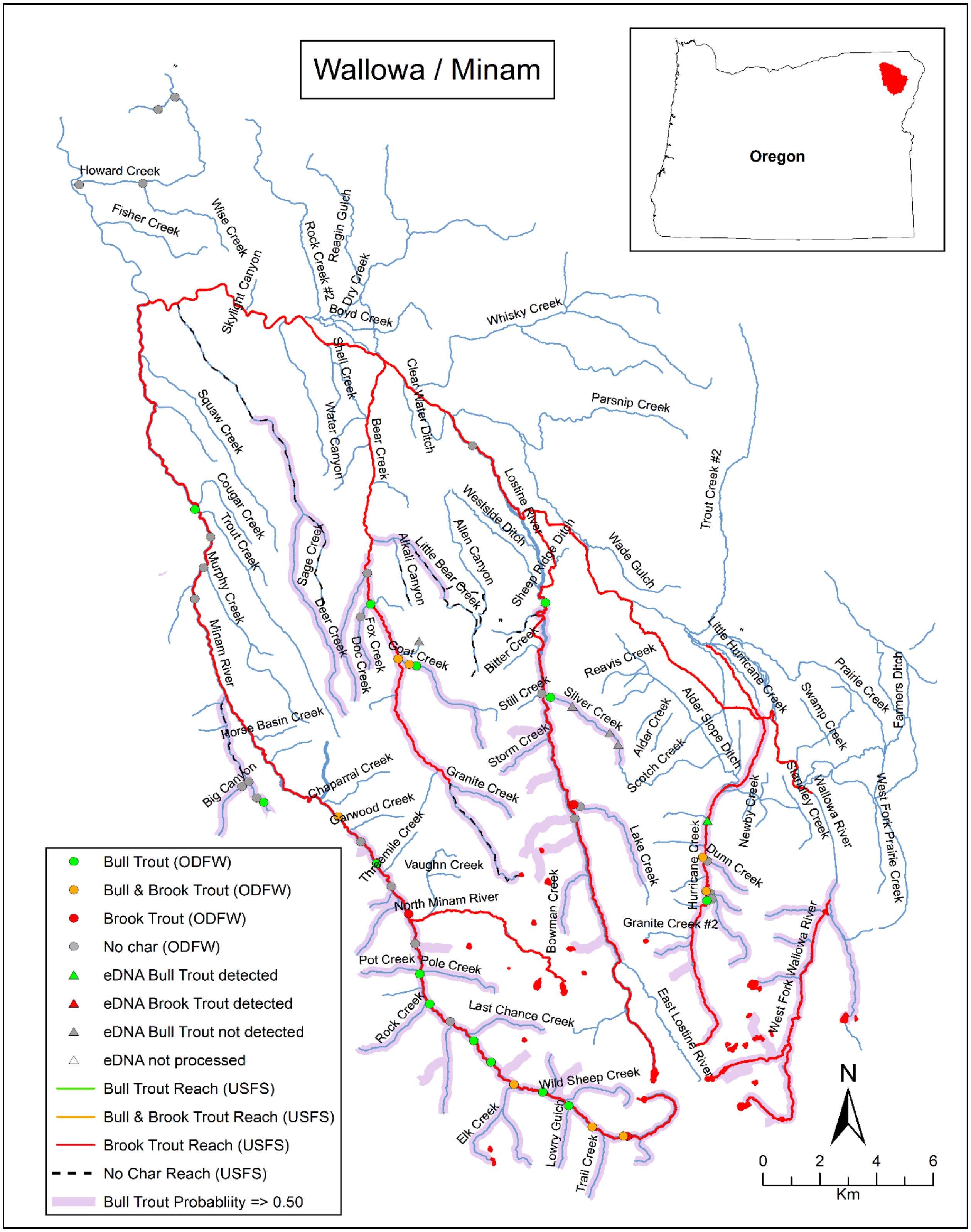

Appendix figure 10. Bull trout and brook trout occurrence and sample sites from ODFW aquatic inventories, USFS survey reaches, and eDNA sampling, and bull trout occurrence probability ≥0.50 (data from J. Dunham, USGS) in the Umatilla core area.



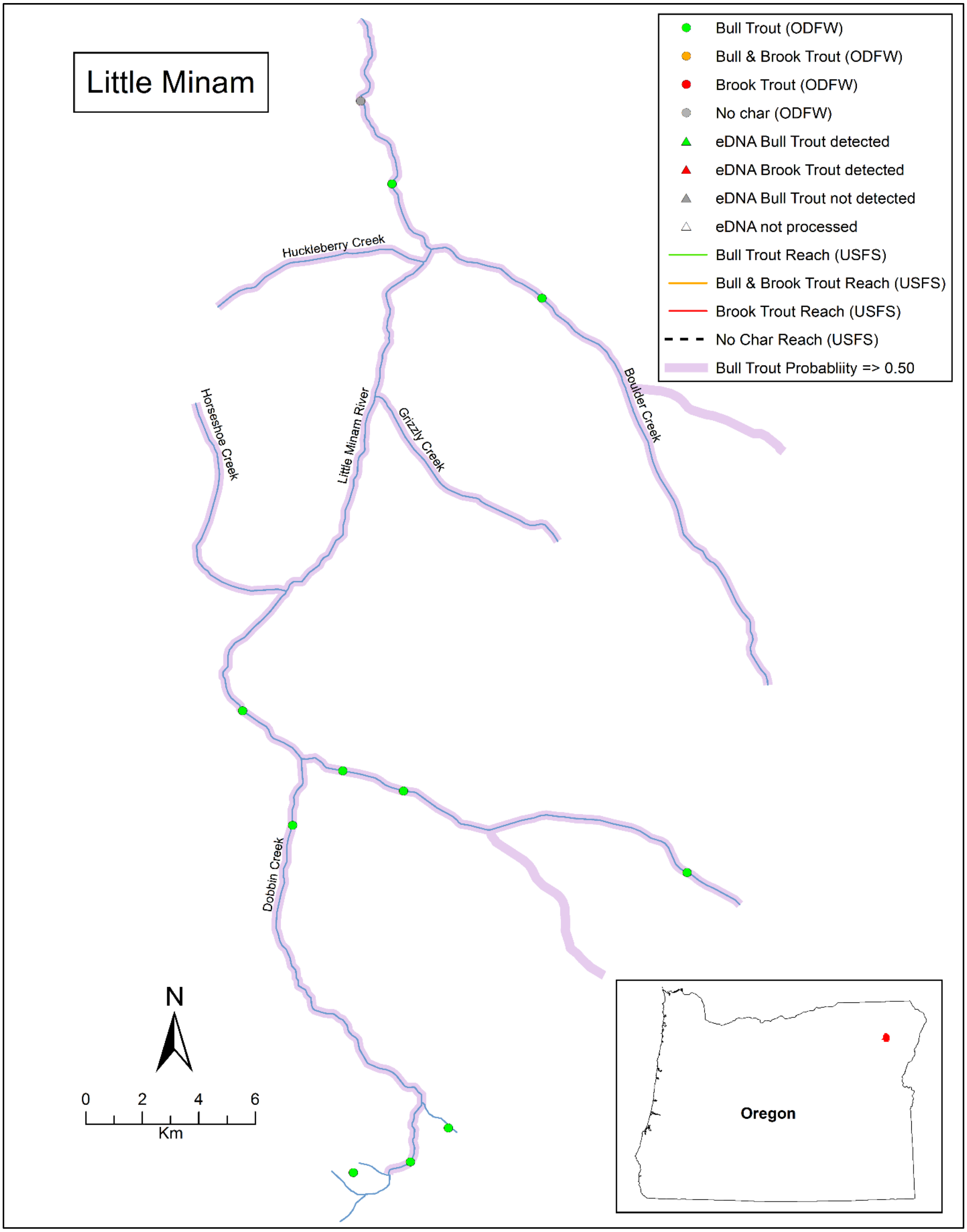

Appendix figure 11. Bull trout and brook trout occurrence and sample sites from ODFW aquatic inventories, USFS survey reaches, and eDNA sampling, and bull trout occurrence probability ≥0.50 (data from J. Dunham, USGS) in the Upper Grande Ronde core area.



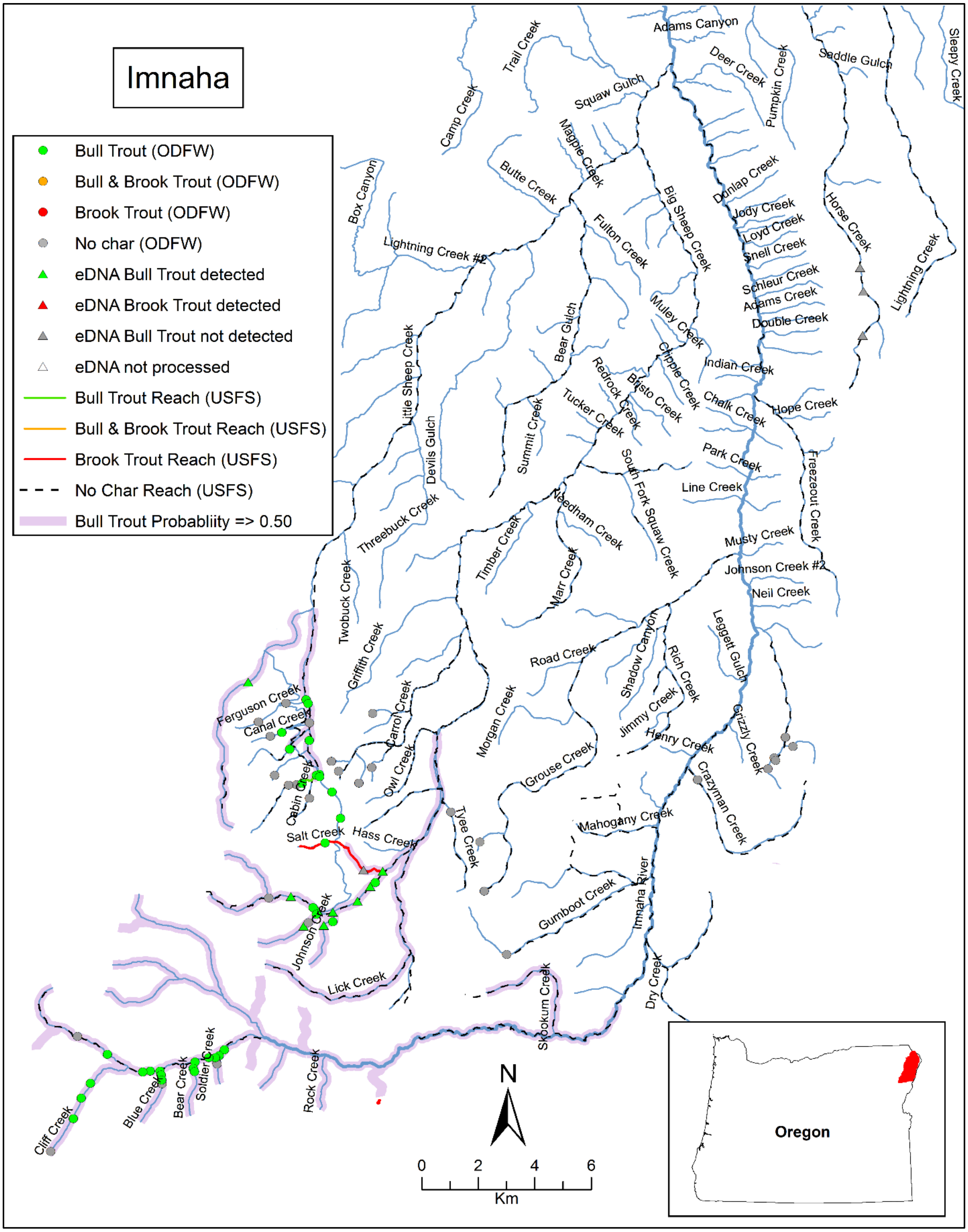

Appendix figure 12. Bull trout and brook trout occurrence and sample sites from ODFW aquatic inventories, USFS survey reaches, and eDNA sampling, and bull trout occurrence probability ≥0.50 (data from J. Dunham, USGS) in the Lookingglass/Wenaha core area.




Appendix figure 13. Bull trout and brook trout occurrence and sample sites from ODFW aquatic inventories, USFS survey reaches, and eDNA sampling, and bull trout occurrence probability ≥0.50 (data from J. Dunham, USGS) in the Wallowa/Minam core area.




Appendix figure 14. Bull trout and brook trout occurrence and sample sites from ODFW aquatic inventories, USFS survey reaches, and eDNA sampling, and bull trout occurrence probability ≥0.50 (data from J. Dunham, USGS) in the Little Minam core area.




Appendix figure 15. Bull trout and brook trout occurrence and sample sites from ODFW aquatic inventories, USFS survey reaches, and eDNA sampling, and bull trout occurrence probability ≥0.50 (data from J. Dunham, USGS) in the Imnaha core area.

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