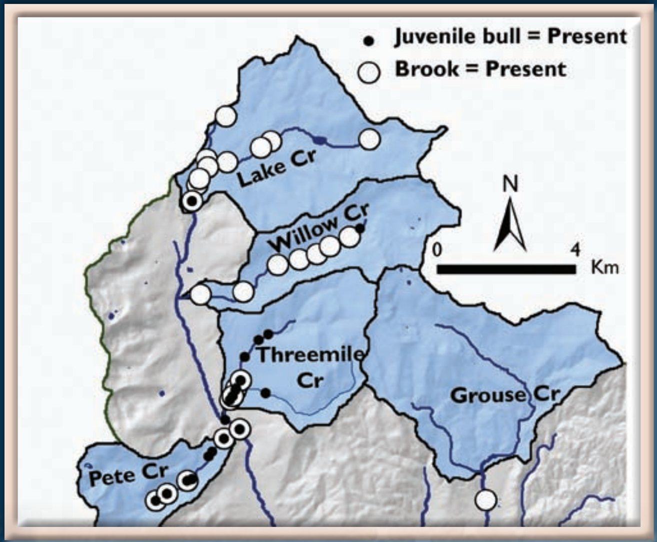
A Watershed-Scale Monitoring Protocol for Bull Trout

Dan Isaak, Bruce Rieman, and Dona Horan



United States Department of Agriculture
Forest Service / **Rocky Mountain Research Station**

General Technical Report
RMRS-GTR-224

April 2009

Isaak, Dan; Rieman, Bruce; Horan, Dona. 2009. **A watershed-scale monitoring protocol for bull trout.** Gen. Tech. Rep. RMRS-GTR-224. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 25 p.

Abstract

Bull trout is a threatened species native to the Pacific Northwest that has been selected as Management Indicator Species on several national forests. Scientifically defensible procedures for monitoring bull trout populations are necessary that can be applied to the extensive and remote lands managed by the U.S. Forest Service. Distributional monitoring focuses primarily on temporal patterns of occurrence within suitable habitat patches, has minimal field sampling requirements, and can provide inference regarding large areas relevant to land management. This document describes: (1) using a geographic information system to stratify a river network into suitable and unsuitable habitats, (2) determining sample sizes and locations, (3) field sampling techniques, (4) basic trend analysis, and (5) an example application and cost estimates derived from a pilot project in Idaho.

Keywords*:* bull trout, distributional monitoring, trends, habitat patches, stream temperature

Authors

Dan Isaak is a postdoctoral Fisheries Biologist with the Rocky Mountain Research Station Boise Aquatic Sciences Laboratory in Boise, ID. He holds a B.S. from South Dakota State University, an M.S. from the University of Idaho, and a Ph.D. from the University of Wyoming. He has worked in native fish conservation and fisheries management and research in the western U.S. for the past 16 years and has primary research interests in climate change and landscape-scale modeling assessments for stream fish and habitat.

Bruce Rieman is an Emeritus Research Fisheries Biologist with the Rocky Mountain Research Station Boise Aquatic Sciences Laboratory in Boise, ID. He holds B.S., M.S. and Ph.D. degrees from the University of Idaho. He has worked in native fish conservation and fisheries management and research in the western U.S. for the past 32 years.

Dona Horan is a Fisheries Biologist with the Rocky Mountain Research Station Boise Aquatic Sciences Laboratory in Boise, ID. She holds a B.S. degree from University of California, Berkeley and a M.S. degree from Utah State University. She has worked in native fish conservation and fisheries management and research in the western U.S. for the past 15 years and provides technical support in GIS, database management, and data collection.

You may order additional copies of this publication by sending your mailing information in label form through one of the following media. Please specify the publication title and number.

Publishing Services

Telephone	(970) 498-1392
FAX	(970) 498-1122
E-mail	rschneider@fs.fed.us
Web site	http://www.fs.fed.us/rmrs
Mailing Address	Publications Distribution Rocky Mountain Research Station 240 West Prospect Road Fort Collins, CO 80526

Cover photos and images clockwise from top*: A bull trout sampled from an Idaho stream (photo by B. L. Gamett, U.S. Forest Service). Locations of stream surveys to determine distributions of bull trout and brook trout in suitable habitat patches within the Secesh River Watershed. See Figure 14 in Section 8 for details. Field crews electrofishing for bull trout on Rabbit Creek in Idaho (photo by Tammy Hoem, U.S. Bureau of Reclamation).*

Contents

A Watershed-Scale Monitoring Protocol for Bull Trout

Dan Isaak, Bruce Rieman, and Dona Horan

Introduction

Bull trout (*Salvelinus confluentus*) are native to much of the Pacific Northwest and significant portions of western Canada. Although bull trout remain widely distributed throughout this range, local extinctions and population declines are common (Rieman and others 1997), which prompted the U.S. Fish and Wildlife Service (USFWS) to list the species as threatened under the Endangered Species Act (ESA) in the late 1990s (USFWS 1998, 1999). Numerous factors have contributed to declines in bull trout populations, including: (1) invasions by non-native brook trout (*Salvelinus fontinalis*; Rich and others 2003; Rieman and others 2006), (2) management activities that degrade and fragment stream habitats (Dunham and Rieman 1999; Rieman and McIntyre 1995), and (3) potential reductions in forage supply and stream productivity from reduced populations of anadromous fish (Gende and others 2002). Environmental changes driven by a warming climate may also be a growing threat (IPCC 2007; Rieman and others 2007) and could include warmer stream temperatures (Mote and others 2005; Webb and others 2008), more variable stream flows (Hamlet and Lettenmaier 2007; Stewart and others 2005), and increased incidence of wildfires and channel-reorganizing events (Dunham and others 2007; Gavin and others 2007; Running 2006; Westerling and others 2006).

As part of the ESA recovery process, agencies must monitor bull trout populations for determination of status and trend. The USFWS has worked to synthesize existing data from many agencies for this determination (USFWS 2002, 2008a), and has also explored development and application of standardized inventory procedures (USFWS 2008b). Within the U.S. Forest Service (USFS), there is similar impetus for monitoring of bull trout because the species has been selected as a Management Indicator Species (MIS) on several national forests (e.g., Payette National Forest and Boise National Forest). Additionally, the specificity of its habitat requirements often restricts bull trout to relatively pristine, high-elevation areas, which coupled with certain life history traits (i.e., fall spawning and minimal straying among populations), makes the species especially vulnerable to the effects of a warming climate (Rieman and others 2007; Whitely and others 2006). Regardless of the rationale, multiple factors point to the need to monitor bull trout populations.

The goal of this report is to develop a bull trout monitoring protocol that provides the following: (1) distributional assessments of extant populations in habitats suitable for bull trout, (2) determination of trends in bull trout populations, and (3) identification of factors that affect both. The protocol is designed to be rapid, flexible, cost-effective, and statistically rigorous. It can provide data useful for basic trend detection in demographic parameters at stream to forest scales and also guides collection of tissue samples that could facilitate genetic monitoring if this becomes a priority. Data collected with the protocol can be used to parameterize habitat occupancy and detection efficiency models, which allow sampling designs to be refined and made more efficient. To demonstrate application of the protocol, the last section of this report describes pilot work done in the Secesh River Watershed of central Idaho.

Section I: Challenges for Monitoring Bull Trout

Monitoring protocols for aquatic species have traditionally been based on trends in abundance measured at a limited number of sites. Previous work with bull trout and other salmonids highlight several limitations to monitoring abundance for detecting trends, including: (1) low statistical power (Ham and Pearsons 2000; Maxell 1999), (2) errors in estimating abundance (Dunham and others 2001; Peterson and others 2004), (3) high population variability (Platts and Nelson 1988), (4) a weak connection between abundance and habitat (Fausch and others 1988), and (5) high costs of rigorous abundance estimates, which limit the number of sample sites and the geographic scale of inference (Al-Chokhachy and others 2005; USFWS 2008b). Abundance monitoring has also tended to focus sampling in areas of high abundance and quality habitats for the target organism (Isaak and others 2003). These areas are typically more resistant to change because of inherent productivity levels or demographic support from nearby areas and may, therefore, provide less sensitivity than other areas (Isaak and Thurow 2006). Many of these problems are exacerbated for bull trout, which often exist at low densities, have diverse life histories, and occur in remote areas where logistical constraints make sampling difficult.

The extensive lands managed by the USFS require monitoring that can be applied rapidly and inexpensively, yet provide accurate trend detection and scientifically valid answers. Monitoring approaches that focus on species distributions and temporal patterns of occurrence overcome many of the limitations associated with abundance monitoring and are being broadly adopted (MacKenzie and others 2002, 2006). Monitoring distributions requires less intense sampling at individual sites than measuring abundance. Also, depending on the monitoring goals and ecological requirements of individual species, sampling can be continuously distributed in space (e.g., assessments for generalist species or communities) or restricted to patches of suitable habitat (e.g., assessments for habitat specialists or single species). If suitable habitats constitute a small proportion of the total area, sampling effort may be further reduced (Guisan and others 2006). Distributional monitoring, therefore, often makes it possible to sample larger and more representative areas for many species and provides information at scales relevant to land management.

The restrictive thermal requirements of bull trout make patch-based assessments particularly appropriate at the southern extremity of the species range (Dunham and Rieman 1999; Dunham and others 2003a). The coldest stream habitats are typically at the highest elevations in mountain landscapes and are often separated by warmer lengths of stream. This creates disjunct networks of suitably cold water across the headwaters of river drainages (Poole and Berman 2001). A bull trout patch can be considered one of these networks where temperatures are cold enough to support spawning and early juvenile rearing (Dunham and others 2003a). Emphasis is placed on reproductive life history stages because although larger bull trout may move downstream to larger rivers, lakes, or reservoirs for overwintering or foraging, these movements are not requisite for completion of the life cycle. Additionally, because spawning salmonids also home to natal areas (Neville and others 2006; Quinn 2005), these patches of suitable habitat may also be reproductively isolated and approximate the boundaries of local populations, which are a fundamental unit of species conservation (Dunham and others 2003a; USFWS 2002; Whitely and others 2006).

Dunham and Rieman (1999) found that bull trout populations in the Boise River basin were strongly linked to suitable habitat patches and the probability of occurrence was positively related to patch size, proximity to other occupied patches, and indices of watershed disruption. Versions of patch-based monitoring protocols for bull trout are currently being applied by the Boise National Forest and Sawtooth National Recreational Area and have been proposed for broader application within the USFWS bull trout recovery planning process (USFWS 2008b). Although intuitively simple, patch-based distributional monitoring poses a series of challenges that include: (1) designating suitable habitat patches, (2) designing sampling strategies for suitable habitats, (3) minimizing the potential for false absences, and (4) detecting changes through time. Each of these challenges is discussed in detail below.

Section II: Designation of Bull Trout Patches

Biological Criteria

Bull trout patch delineations should be based on objective, repeatable, and defensible biophysical criteria. The most direct method of patch delineation is based on observed distributions of bull trout. In the Boise River basin, for example, Rieman and McIntyre (1995) found that although juvenile bull trout (<150 mm) occurred at elevations as low as 1,520 m, the frequency of occurrence increased sharply at 1,600 m. Subsequent studies in this basin delineated patches using this 1,600-m elevation threshold (Dunham and Rieman 1999; Rieman and McIntyre 1995; fig. 1). Distributions of smaller fish were used in patch delineations because their restricted movements during initial rearing make them a better indicator of natal habitat boundaries. Although simple to apply, this approach requires biological data that may not exist and is less relevant in areas where distributions lack clear elevation thresholds (e.g., basins where stream temperatures are suitably cold in most areas).

Rieman and others (2007) extended this approach to a broader geographic area using data on juvenile bull trout distributions from 76 streams across the Interior Columbia River basin. A statistical model was built to predict the lower elevation limit of juvenile bull trout from latitude and longitude (fig. 2). This model accounted for 74% of the variation in the lower elevation limit of juveniles and revealed strong gradients of decreasing elevation from south to north and east to west that mirrored gradients in mean annual air temperatures.

The Rieman and others (2007) model can provide useful approximations of natal patches within areas of the Interior Columbia River basin that lack distribution data, but predictions are expected to be crude and will not reflect the detailed variation in distributions associated with local conditions. Additionally, data used in model construction reflected bull trout distributions from 1980 to 1995 that may change in response to climate warming (Rieman and others 2007).

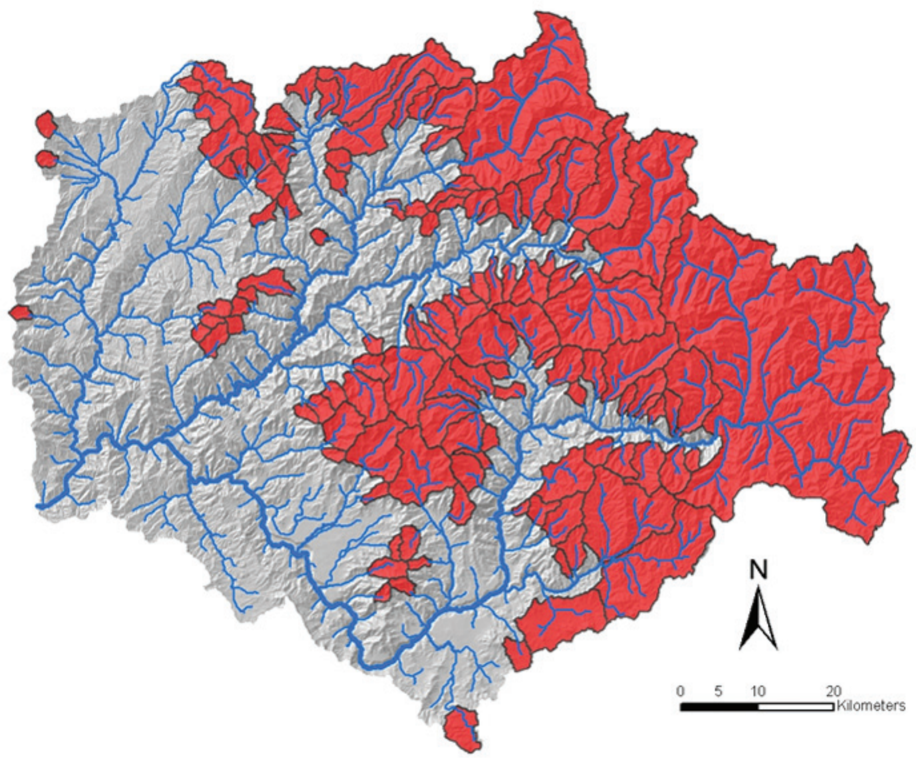


Figure 1. Distribution of suitable bull trout patches within the Boise River basin based on a 1,600 m elevation limit derived from downstream extent of juvenile bull trout.

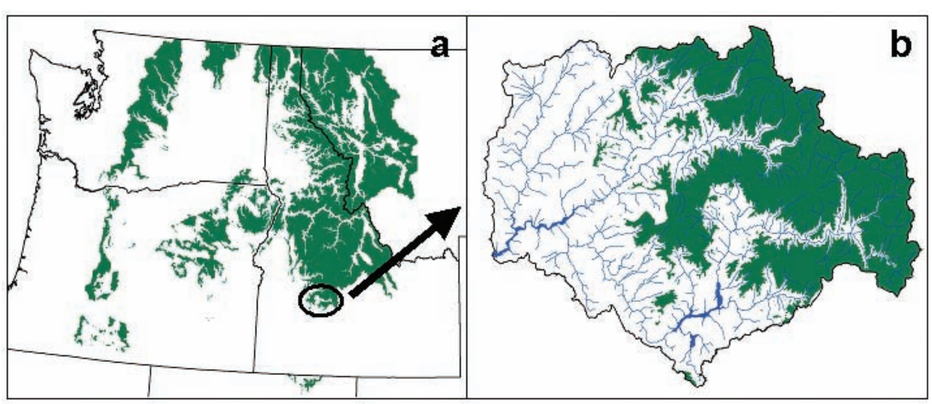


Figure 2. Distribution of suitable bull trout habitat from a model predicting the lower elevation limit of juveniles across the Interior Columbia River basin (panel a). Distribution of habitat predicted within the Boise River basin from the same model (panel b).

Environmental Criteria

An alternative approach to patch delineations could rely on environmental characteristics. A logical choice, given the restrictive thermal requirements of bull trout, is to focus on stream temperature. Temperature data are often more easily collected than biological data, may already be archived in regional or forest-specific databases, and can be used to make inferences about habitat distributions for other aquatic species if that becomes a priority. Delineating a patch boundary with temperature data may be as simple as interpolating between two thermograph sites to determine where a designated temperature threshold is passed or could entail development of predictive statistical models.

If models are built, useful covariates may be derived from spatial data and temperature predictions mapped across all areas of interest. When a time series of data is available, covariates could include climate variables such as air temperature and stream flow, thereby providing a dynamic aspect to model predictions and the ability to accommodate local environmental trends. Models of this type are currently being developed and tested in the Boise River basin (fig. 3; D. Isaak, unpublished data).

Delineating patches based on stream temperature attributes requires that specific temperature metrics and threshold values be chosen. Numerous temperature metrics are available (Dunham and others 2005) and Rieman and Chandler (1999) summarized juvenile bull trout occurrence relative to several common metrics derived from an extensive regional temperature database. In analyses based on these data, Dunham and others (2003a) found that the probability of occurrence for small bull trout dropped below 0.5 when daily summer maximum temperatures exceeded 16 °C, but occurrence remained common at daily maximums of 18-19 °C (fig. 4; Rieman and Chandler 1999). Gamett (2002) examined relationships between bull trout and 18 temperature metrics in the Little Lost River drainage of central Idaho. Most metrics were strongly correlated, but he concluded that mean summer temperature provided the best overall measure of bull trout habitat. Bull trout were present at all sites where mean temperature was less than 10 °C, 40% of sites where mean temperatures were <12 °C, and

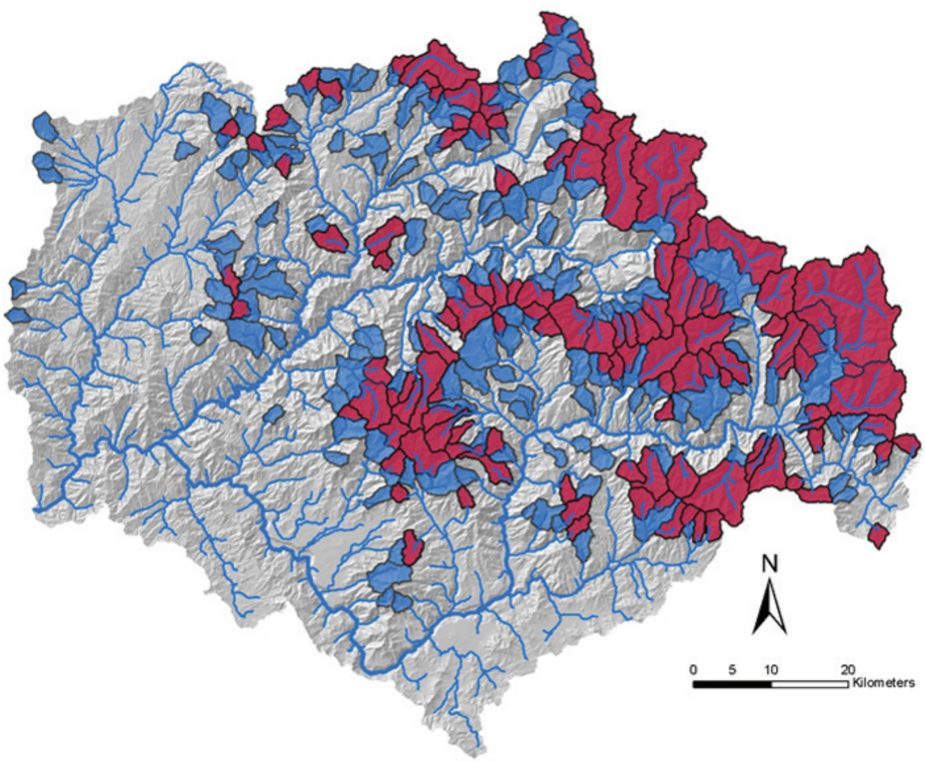


Figure 3. Distribution of suitable bull trout patches within the Boise River basin based on maximum summer temperatures of 15 °C in 1993 (blue) and 2006 (purple). Environmental trends associated with warming air temperatures, decreasing summer flows, and several fires reduced the area of habitats predicted to be suitable during this 13-year period (D. Isaak, unpublished data).

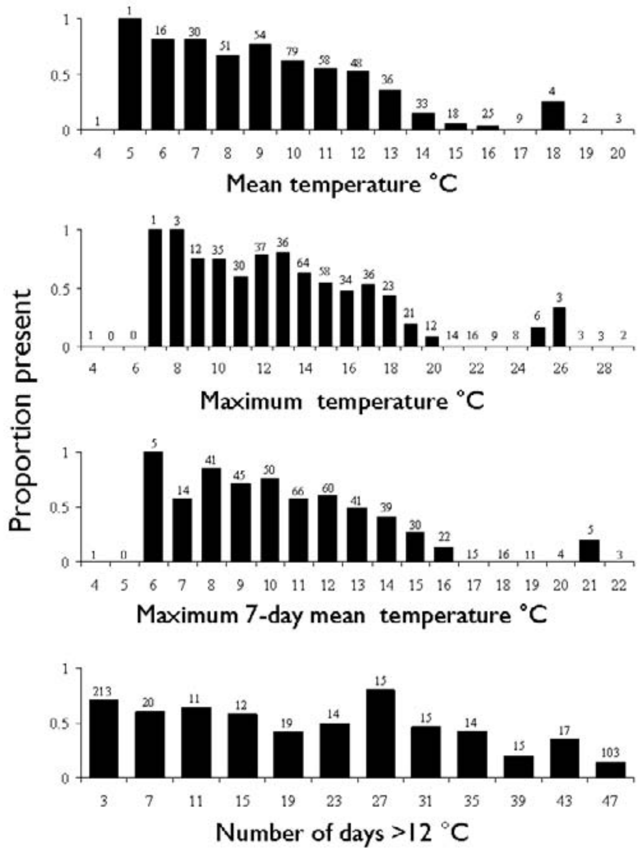


Figure 4. Frequency of juvenile bull trout occurrence relative to four summer stream temperature metrics. Numbers above bars are sample sizes. Data are from a regional database compiled by Rieman and Chandler (1999).

no sites where means exceeded 12 °C (Gamett 2002). These results are also consistent with recent surveys in 12 central Idaho streams where bull trout occasionally occurred in mean temperatures nearing 13 °C and maximum weekly maximum temperatures (MWMT) of 17.5 °C. However, high abundances were rare at means >11 °C or MWMTs >15 °C (D. Isaak, unpublished data; Rieman and others 2006).

Depending on the goals of the study, threshold values used to delineate patches can be set liberally or conservatively (table 1). Monitoring protocols on the Boise National Forest use a relatively conservative criterion of ≤15 °C MWMT (Kellett, personal communication). Conservative criteria are most appropriate where bull trout distributions are well known or where sampling efficiency is a priority. However, if patch criteria are set too conservatively, sampling will be limited to the highest quality habitats and the strongest populations. These areas may be more resistant to population change and less sensitive to environmental change (Isaak and Thurow 2006). More liberal criteria may be more appropriate in initial basin assessments to ensure that a wide range of habitats are surveyed and odds are increased that most extant bull trout populations will be detected. The specific temperature metric chosen for patch delineations is less important because of the high correlation among temperature metrics (Dunham and others 2005; Hillman and Essig 1998). If comparisons between protocols are desired or users wish to change metrics, Dunham and others (2005) provide instructions for inter-metric conversion.

To focus sampling within patches, additional physical criteria may be employed. For example, bull trout often occur in relatively steep sections of stream, but densities decline as slope increases (Dunham and Rieman 1999; McCleary and Hassan 2008). Once slopes exceed 15-20%, streams are unlikely to be primary spawning and rearing areas and geologic barriers to migration become increasingly common (Adams and others 2000). If steep slopes occur at the terminal end of a stream network, these areas can be safely excluded from sampling.

Similarly, bull trout are rarely found in streams ≤1-2 m in width (Dunham and Rieman 1999; Rich and others 2003; Rieman and McIntyre 1995; Watson and Hillman 1997). If bull trout do occur in these streams, they are typically part of a larger network within an occupied patch (Dunham and Rieman 1999). In the Boise River basin, approximately 400 ha of contributing area are required for streams to exceed 2 m. Knowing the relationship between contributing area and stream size is useful because contributing areas are easily calculated from digital elevation models (DEMs) in a geographic information system (GIS), which allows significant portions of the stream network

Table 1—Stream temperature metrics commonly used to delineate bull trout habitat patches.

Thermal suitability	Mean summer temperature (°C)	Summer maximum temperature (°C)	MWMT (°C)
High	≤10	≤16	≤15
Medium	>10 and ≤12	>16 and ≤19	>15 and ≤17.5
Low	>12	>19	>17.5

to be excluded from sampling considerations. Some biologists also believe that spawning rarely occurs in large streams and local knowledge could be used to truncate patches at confluences with larger rivers or streams (e.g., >4th-order; Dunham and others 2003a). When used in combination, stream size, slope, and temperature or elevation criteria can greatly reduce the area of stream habitat where monitoring is conducted. In the Boise River basin, for example, application of these criteria reduced the amount of potential stream habitat from 6,000 km to 1,000 km (Dunham and Rieman 1999).

After initial patch designations are made, they should be reviewed and refined by district or regional biologists to account for local conditions and ensure that all known populations or streams with the potential to support bull trout are identified. In some instances, patches may be predicted to meet temperature and minimum size criteria, but are isolated by man-made or geologic barriers. Other streams may support populations, but patching criteria did not identify the area as a potentially suitable patch. Neither of these exceptions should initially disqualify areas as valid habitat patches.

Section III: Classification of Patches for Sampling

Once final patch designations are made, patches should be classified to further focus sampling efforts. Suggested categories could include: (1) patches supporting bull trout populations (i.e., spawning or early rearing have been documented) based on recent sampling, (2) patches that have been sampled and bull trout were not detected but conditions could support a population or patches where bull trout have been detected but observations are not recent, (3) areas that have been sampled, bull trout were not detected, and habitat conditions are degraded and incapable of supporting a population, and (4) patches that have not been sampled (fig. 5).

The frequency with which patches are sampled will be contingent on available funding and personnel, total number of patches, their classifications, and sampling intensity. However, attempts should be made to sample all patches at least once every 7 years. This would provide at least two status assessments during the approximate length of forest management plans (~15 years). Sampling at more frequent intervals will generally be less informative because the primary monitoring goal is to detect population occurrence and this may not change substantially over time spans less than the 5 to 7 year generation time of bull trout (Rieman and Allendorf 2001).

Initially, all patches in categories 2 and 4 should be prioritized for inventory. These patches need to be surveyed to definitively establish current bull trout occurrence and complete an initial distributional assessment. If available resources permit, patches in category 1 could also be sampled, preferably no later than 7 years from the last documented occurrence of bull trout. After a complete initial assessment of all patches, survey results should be used to update patch classifications (fig. 5). Subsequent assessments will have only three patch classifications (1, 2, and 3), as unsurveyed patches will no longer exist. Most sampling will be of patches in category 1 or 2, but category 3 patches may be sampled if environmental conditions or limiting factors have improved (e.g., culvert barrier removed or brook trout population eradicated) to the point that bull trout populations may be supported. The temptation may exist to avoid sampling category 2 patches (previously unoccupied, but suitable) during subsequent assessments, but resampling of these patches is necessary both to confirm earlier results and to document colonization of new areas.

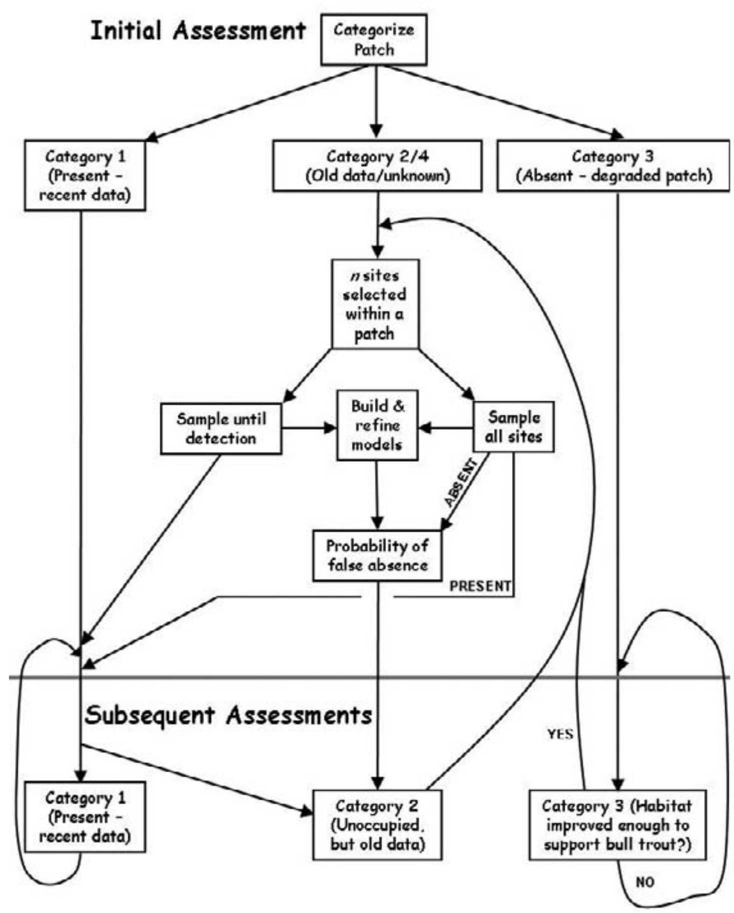


Figure 5. Flow chart depicting patch categorization and sampling sequence for initial and subsequent bull trout assessments.

Section IV: Sampling of Bull Trout Patches

Patch delineations identify the locations of potential bull trout habitats, but sampling is required to determine whether these habitats host populations. Before starting new sampling efforts, however, existing databases should be reviewed to identify patches that already support populations. Relevant databases need not be limited to U.S. Forest Service records, but can come from any natural resource agency and a variety of sampling techniques (e.g., snorkeling, electrofishing, weirs, redd counts, etc.). The main requirement is recent and reliable documentation of spawning or rearing activity within a patch. Verification should not include observations of larger fish (e.g., >150 mm) because subadult bull trout may range widely (Monnot and others 2008). Also, records older than the generation time of bull trout (5-7 years) should not be taken as evidence of presence. Where recent data are available, patches can initially be classified in category 1 (bull trout present). Depending on the intensity of recent fish surveys in a study area, this review may significantly reduce the field effort needed to complete an initial assessment. Continued collaboration and coordination with other agencies working in a study area may also reduce future field efforts and maximize utility of available U.S. Forest Service resources.

In patches where recent data do not confirm bull trout presence, or where more definitive baselines are desired for future comparisons, formal stream surveys must be conducted. It will not be possible, however, to sample all areas given the length of suitable habitat in many patches. Instead, a small subset of sites can be surveyed to provide inference regarding bull trout presence. If juvenile bull trout are captured at one of these sites, occurrence can be concluded unambiguously. Similar certainty is not possible, however, when bull trout are not captured because two possibilities exist: either a population does not exist, or was present, but undetected (i.e., a false absence). It can never be proven that bull trout were absent—only that the probability of reaching this conclusion erroneously was reduced to an acceptable level (e.g., <0.01, <0.10). There is no standard regarding an acceptable false absence rate, so biologists and managers must make this decision within the context of local policy and available sampling resources. If the false absence rate is set sufficiently low, undetected populations will presumably exist at very low densities or within restricted areas. Such marginal populations may already be declining toward local extinction or be susceptible to extirpation from stochastic mechanisms. For practical purposes, these populations may exist, but could be discounted as demographic or ecological "lost causes."

The false absence rate depends on the number of sites sampled within a patch and site-level detection probability. Site-level detection depends on the number of bull trout at a sampling site (i.e., each fish is a chance to detect presence) and the efficiency of a sampling technique (i.e., probability that individual fish is captured given it is present). The false absence rate is calculated as:

$$f = (1 - p)^n \quad (1)$$

where n = the number of sites sampled in a patch and p is the site level detection probability assuming all sites have the same probability (Peterson and Dunham 2003). So if a monitoring protocol required a 0.05 false absence rate, and a sampling technique with $p = 0.30$ was used, 8-9 sites would have to be sampled within a patch (fig. 6). Alternatively, using a sampling technique with higher detection, $p = 0.50$, would require 4-5 sites to yield the same level of confidence. Figure 6 shows curves for a range of detection probabilities and is output from an Excel spreadsheet calculator developed by Peterson and Dunham (2003).

A naïve estimate of p (i.e., ignores environmental factors causing variation in p) can be obtained from empirical estimates based on sampling multiple sites in patches where bull trout are detected as:

$$p = m/n \quad (2)$$

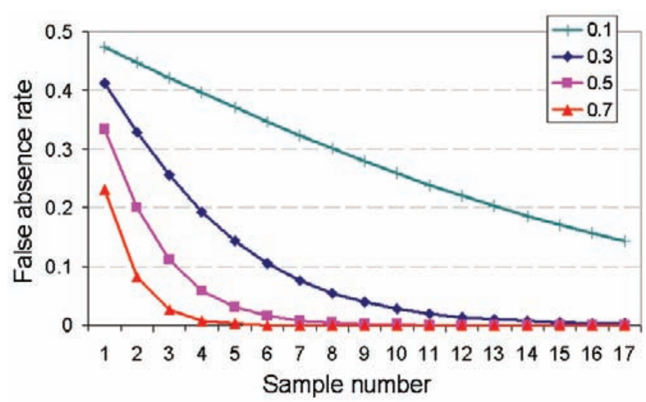


Figure 6. Probability of incorrectly concluding bull trout absence from a patch relative to the number of sample sites and site-level detection probability. Calculations made assuming no prior knowledge about patch occupancy.

where m = number of sites where bull trout are detected in a patch and n = number of sites sampled within a patch (Wintle and others 2004). Data from previous surveys of bull trout patches suggest values of 0.36-0.39 for single-pass electrofishing through 20 to 40 m of stream (D. Isaak, unpublished data; Rieman and others 2006). Comparable estimates are not available for snorkeling, which is another potential sampling technique, but sampling efficiencies for small bull trout suggest night snorkeling could have slightly higher p and day snorkeling a lower p (Peterson and others 2004; Thurow and others 2006). Empirical estimates would have to be compiled before these methods could be applied with confidence within the context of this protocol.

If p of the chosen sampling method is low, false absences at the site level could be common and bias estimates of p. Tyre and others (2003) suggest this bias is problematic when false absence rates exceed 50%. Data from previous electrofishing surveys, however, suggest false absences will be well below 50%, given the sampling efficiency of this technique and typical densities of juvenile bull trout (Peterson and others 2004). If false absences become an issue, their effects can be mitigated by measuring relevant habitat covariates and using them to model better estimates of p and bull trout occurrence (MacKenzie and others 2002; Tyre and others 2003). These estimates can be made using freely available software such as PRESENCE 2.0 (www.mbr-pwrc.usgs.gov/software/; MacKenzie and others 2002).

Regardless of false absence rates, a simple set of covariates relevant to bull trout occurrence and sampling efficiency should be recorded at all sites within a patch. These data could be used to test for biased estimates of p and develop logistic regression models that predict bull trout occurrence. Once calibrated to the study system, these models can be used to refine and focus future sampling efforts. In some patches, for example, efforts could be focused on sites with the highest probability of occurrence and sampling ended once bull trout were detected, perhaps after sampling only one or two sites. In other instances, predictions of occurrence probability could be used as prior probabilities to adjust required sample sizes (Peterson and Dunham 2003)—with lower quality patches generally requiring less sampling to be confident of bull trout absence than higher quality patches. Finally, occurrence models could also be used to revise initial estimates of false absence rates based on naïve estimates of detection probability.

Section V: Site Selection Within Patches

Sample site locations within each patch can be determined using a variety of designs (e.g., representative reach, systematic, random, cluster, or convenience sampling). Probabilistic designs are usually best because site selection is randomized, each site has an equal selection probability, and statistically valid, unbiased estimates are provided. Purely random selection, however, can also result in spatial clustering of sites that may not adequately represent the strong environmental gradients that typically occur in small mountain streams. To address this issue, the Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP) developed the Generalized Random Tessellation Stratified design (GRTS; Stevens and Olsen 2004). GRTS uses a randomized hierarchical grid that arrays sites throughout a stream network to achieve spatial representation. GRTS designs can be customized to assist with the development of specific monitoring protocols for stream networks using web-based resources available at http://www.epa.gov/NHEERL/arm. Users identify the area of interest, a digital representation of the stream network (usually the 1:100,000 National Hydrologic Dataset), and the desired density of sample sites. Site density should be set so that the number of GRTS sites exceeds the target number of sample sites within a patch to provide alternates if crews are unable to sample some sites.

Selection of sample sites from the GRTS list should be based on the unique identifier associated with each GRTS site. So, for example, if 20 GRTS sites are generated for a patch, and eight will be sampled in the field, the sites with the eight lowest identifiers are selected in sequential order. Once in the field, sites can be sampled in any sequence that is logistically convenient whenever all sites are sampled. In some instances (e.g., after detection efficiency models are developed or when sampling in logistically challenging environments), efficiency can be maximized by sampling sites with the highest probability of occurrence (fig. 5). Once bull trout are detected, further sampling is unnecessary unless done for other reasons (e.g., development and refinement of detection efficiency and occurrence models or describing fish distributions within a patch). If bull trout are not detected, all of the sites within a patch must be sampled to reach the predefined probability of occurrence without detection. If fewer sites are sampled, the probability of occurrence can still be calculated but it will be higher than intended.

Section VI: Site Sampling Methods

Biological Samples

Logistical constraints associated with sampling bull trout habitats limit potential sampling techniques. Day or night snorkeling can be effective and are the best options where there are overriding concerns about fish injuries (Thurow and others 2006; Thurow and Schill 1996). A disadvantage of these techniques is that fish are not usually captured, which makes identification and measurement less accurate and presents difficulties where brook trout hybridization is an issue (Kanda and others 2002; Spruell and others 2001). Electrofishing is not similarly limited and preliminary estimates of p already exist that can be used to plan sampling efforts. Because it will be the obvious choice in many circumstances, the following discussion assumes that most sampling will be conducted by electrofishing.

Sites should be sampled with a standardized protocol to ensure consistency of sampling effort. Crews should navigate to site locations and establish site boundaries. Coordinates for these boundaries should be recorded with a global positioning system (GPS) for later confirmation of site locations. Sample sites will be stream reaches 20-40 m in length. Sampling longer reaches, using blocknets or multiple electrofishing passes, are generally unnecessary unless more detailed population estimates are desired for other purposes. If more intensive sampling is conducted, data from the first pass through 20-40 m of stream should be separated to ensure comparability to data from similar monitoring protocols (USFWS 2008b).

Direct current (DC) should be used with pulse rates and widths set to reduce potential for injury of fish (Temple and Pearsons 2007). Electrofisher settings and operability should be tested prior to sampling. Crews should sample slowly and deliberately, especially near cover components because bull trout densities are usually low and chances to net fish may be rare. Crew members should wear polarized sunglasses to increase visibility. Bull trout may be increasingly susceptible to handling stress as water temperatures increase above 16 °C. During warm days, electrofishing surveys may need to be conducted in the early morning and late evening to reduce the risk of injury.

All fish, regardless of species, should be netted, with the exception of large bull trout (e.g., >25 cm) that may ascend into streams from late spring through fall in preparation for spawning. Although these fish may indicate the likelihood of spawning, this cannot be confirmed without direct observation because bull trout range widely and sometimes occur in non-spawning streams (Monnot and others 2008). These fish should be avoided to minimize the possibility of injuries. In streams that do not support brook trout, young-of-the-year fish may sometimes provide adequate evidence of bull trout occupancy. However, if brook trout are present, discrimination of young-of-the-year fish may be difficult and confirmation of bull trout occurrence will generally require capture of older fish.

Fish collected during sampling should be anesthetized, measured, and identified to species. Hybrids between bull trout and brook trout can be visually classified with good accuracy (>95%) based on pigmentation of the dorsal fin, vermiculations, spotting coloration, and body form. Classification success of genetically pure bull trout is even greater and approaches 100% (Fredenberg and others 2007; Rieman and others 2006). Whenever possible, fin clips from bull trout and suspected hybrids should be taken and archived for possible future genetic analyses. Tissue can be preserved in alcohol or dried in scale envelopes. Digital photos of fish may also provide a useful reference.

Environmental Covariates

Attributes of sample sites and patches that most strongly affect bull trout occurrence and sampling efficiency can be used to develop models that will improve future survey designs. These attributes can be measured in the field or using a GIS. Attributes derived from GIS maps are often surrogates intended to represent local stream conditions (e.g., elevation for temperature, watershed area for stream size). If the correlation between map and local conditions is strong and these attributes are established as important model factors, a GIS could be used to map probabilities of detection and occurrence throughout a stream network—thereby providing a tool for future survey planning. However, field data are needed to establish these linkages and test for consistent relationships with detection probability and occurrence. The list of potential attributes should be refined based on the experience of local managers or as preliminary results dictate, but could include the following.

Stream temperature

Stream temperature is probably the best predictor of habitat quality for bull trout, but several other means are available for measurement. Average thermal conditions may be approximated using a surrogate such as elevation, which is easily obtained from DEMs, paper maps, altimeters, or GPS units in the field. The utility of this surrogate, is based on a simple air temperature—stream temperature relationship (Mohseni and Stephan 1999) that is sometimes weak in the spatially complex topographies of mountain landscapes (Isaak and Hubert 2001). A better choice, when available, is to obtain direct stream temperature measurements derived from continuously recording thermographs. Thermographs could be placed at individual sample sites or at the upstream/downstream extent of sites within a patch and temperatures interpolated. If enough temperature data exist, statistical models can be built and used with a GIS to map temperature predictions throughout a stream network.

A measurement taken with a handheld thermometer at the time of sampling may also be useful. Many salmonids display behavioral differences relative to diel temperature fluctuations, which affect their vulnerability to sampling and overall detection probability (Fraser and others 1993; Thurow and others 2006). Therefore, instantaneous temperature may be an important covariate to consider in models of detection efficiency.

Patch size

The size of a suitable habitat patch is a strong determinant of bull trout occurrence (Dunham and Rieman 1999; Rieman and McIntyre 1995). Bull trout in large patches may be more persistent because population numbers are greater and less susceptible to small population effects. These areas may also support a broader array of habitats, some of which act as refugia during periodic disturbances (Dunham and others 2003b; Rieman and McIntyre 1995). Patch size has often been quantified as watershed contributing area (e.g., Dunham and Rieman 1999), although the length of suitable stream within a patch may also provide a useful measure (USFWS 2008b).

Stream site dimensions

The cross-sectional area of a stream affects the area of water that must be searched for bull trout during a site survey and is inversely related to sampling efficiency and detection probability (Thurow and others 2006). To characterize channel dimensions, measurements should be taken at several regularly spaced transects throughout a site. At each transect, wetted widths should be recorded perpendicular to the direction of flow and depths taken at 1/4, 1/2, and 3/4 of this width. Mean depth is calculated by dividing the sum by four to account for zero depth at each bank (Platts and others 1983). The length of stream sampled at each site also needs to be recorded so that site area or volume can be calculated and fish captures expressed as densities.

Stream slope

Slope is a basic determinant of channel morphology and microhabitat characteristics available to bull trout. As a result, slope may affect sampling efficiency and probability of occurrence. Steep slopes will also often truncate the distribution of suitable habitats near the terminal extent of the stream network. Slope can be measured in the field by a variety of means (Isaak and others 1999) or derived from DEMs in a GIS (Clarke and others 2008; Tarboton 2004).

Brook trout presence

Non-native brook trout hybridize with bull trout and competitively exclude them from suitable stream habitats (Benjamin and others 2007; Rieman and others 2006). Presence or densities of brook trout within patches or sample sites should be recorded.

Undercut banks

Undercut stream banks provide an important element of cover for juvenile fish and significantly affect sampling efficiency for bull trout (Peterson and others 2004; Thurow and others 2006). Undercuts may be defined as areas beneath stream banks, boulders, bedrock, or wood that are solid portions of the stream bank. One classification suggests undercut banks must be at least 5 cm wide and less than 0.25 m above the water surface (see Platts and others 1983 for illustrations). Length of the undercut along each bank should be recorded.

Large woody debris

Pieces of large wood in streams create structural complexity that enhances habitat quality and fish densities, but may also decrease sampling efficiency (Thurow and others 2006). For Rocky Mountain streams in the Interior West, Richmond and Fausch (1995) suggested pieces of wood have a minimum diameter of 10 cm and 1-m length to be considered functionally effective. Large wood can be counted or measured and expressed relative to reach area to provide an index of habitat complexity.

Section VII: Trends In Bull Trout Populations

Previous sections describe the steps necessary to delineate and inventory bull trout habitats across an area of interest. By repeating these assessments through time, monitoring of population status and trends are facilitated. In some areas, populations will expand and unoccupied patches may be recolonized as barriers are removed or actions taken to improve local habitat conditions. Brook trout invasion, a warming climate, fires, or other factors may lead to extirpations and range contractions elsewhere. These changes may be subtle, occur slowly, and be discernable within or among patches. Determining whether broad patterns emerge from these interacting factors and whether the overall status of bull trout is improving, stable, or declining is a challenge, but is the crux of MIS monitoring. General methods for describing trends in bull trout populations are discussed in this section. For more specific applications, readers are directed to the publications cited in the sections that follow and should also consider engaging researchers in collaborative efforts.

Patterns Among Patches

The stability and persistence of many species at landscape scales is often related to the number, size, and relative distribution of discrete populations and suitable habitats (Hanski 1999; Schlosser 1991). The biological and environmental variables collected as part of this protocol provide suitable characterizations of these factors for bull trout. At the completion of each assessment, an inventory of bull trout occupancy within all suitable habitat patches will exist. From each inventory, summary metrics can be derived (e.g., number and proportion of suitable patches occupied, average patch size, size-frequency histograms) to characterize the distribution of bull trout and suitable habitat areas. Comparison of these metrics and spatial patterns of occurrence through multiple assessments may allow determination of general trends (fig. 7).

As the number of status assessments and patch surveys increases, power analyses could be conducted to determine the ability of the monitoring protocol to discriminate changes in patch occupancy of various magnitudes and to optimize the number and frequency with which patches are surveyed (Ham and Pearsons 2000; MacKenzie and others 2006). Determining magnitudes of increase or decrease that are relevant requires consideration of local management objectives and regulatory constraints; whereas the power to detect these changes varies based on the number of patches surveyed, site and patch level detection efficiencies, and number of repeat assessments.

Detailed modeling efforts may also be undertaken to develop state transition (extinction/colonization events) models or occurrence models that link these responses to biological or physical factors associated with bull trout populations. Once developed, these models could be used to predict populations at risk of extirpation or patches that are more likely to be colonized and management actions taken accordingly (Fleishman and others 2002; Pellet and others 2007). Occurrence models could be used to refine future sampling efforts as described above.

The spatial relationship among occupied patches within a habitat network is another important factor affecting the likelihood of species persistence (Calabrese and Fagan 2004). Networks that are better connected may facilitate interpatch movements by individuals that can bolster numbers in small populations or refound unoccupied patches. Numerous ways of describing connectivity exist—from simple measures of nearest neighbor distance to measures that weight the combined influence of all occupied patches in the surrounding network (Dunham and Rieman 1999; Isaak and others 2007). USFWS

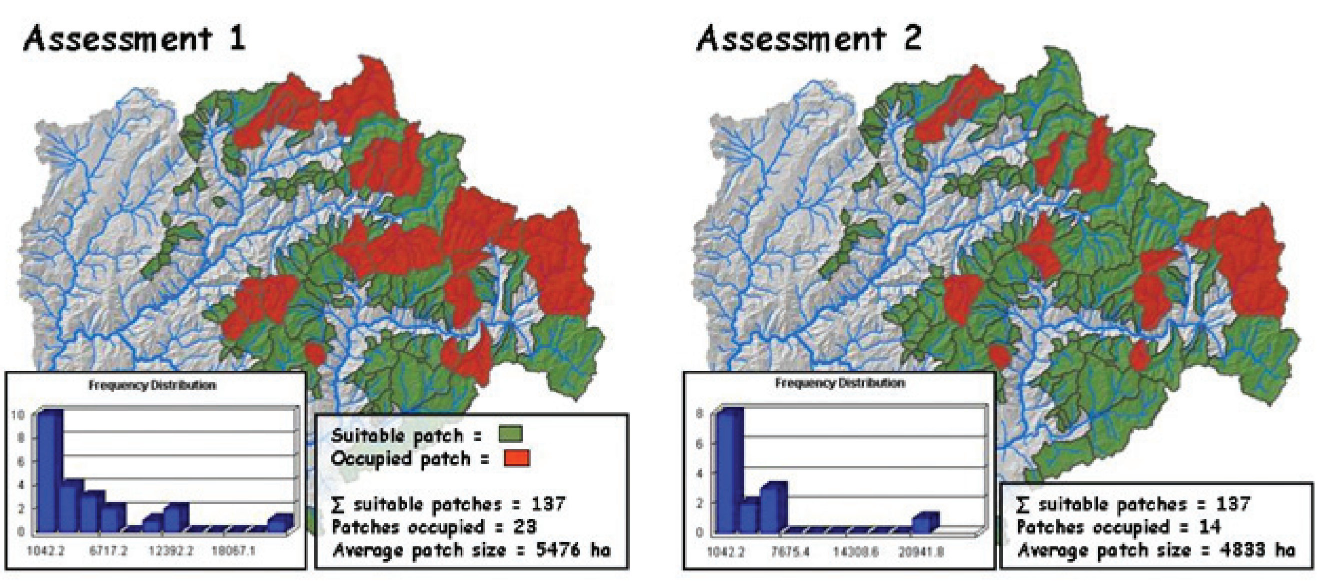


Figure 7. Hypothetical changes in bull trout patch occupancy between two monitoring assessments.

(2008b) developed and tested several connectivity metrics using bull trout data from the Boise River and found that hybrid metrics simultaneously accounting for patch size and connectivity were most informative. Reviews providing more detailed discussions of this topic have been completed by Moilanen and Nieminen (2002) and Calabrese and Fagan (2004). A comprehensive alternative to connectivity metrics is provided by graph theory, which has only rarely been applied to aquatic systems (e.g., Schick and Lindley 2007), but has the potential to identify populations of disproportionate importance and may even predict thresholds where population networks start to collapse (Urban and Keitt 2001).

Patterns Within Patches

In patches with multiple sample sites, data will exist on fish densities, species composition, stream habitat, and possibly genetic structure along gradients from upstream to downstream. These data provide another opportunity for monitoring and could reveal trends within patches that foreshadow changes in occupancy. For example, if stream temperatures warmed over time, bull trout distributions may contract toward cooler, headwater areas within a patch (fig. 8). Similarly, once brook trout colonize a patch, they may displace bull trout from lower elevation sites and could eliminate them entirely depending on local habitat conditions (Rieman and others 2006). As data on bull trout distributions are assembled, it may be possible to develop metrics that indicate extirpation risk based on patterns of occurrence within a patch. Presumably, very small or narrowly distributed populations are more vulnerable to local extinction and concerns should be greater in these areas. If trends toward population reductions within patches are detected early, actions might be initiated to avoid costly interventions at a later date or the possible loss of a bull trout population.

A variety of statistical techniques that use repeated measures for trend detection are available and could be used in conjunction with the habitat or biological variables measured with patches (Kutner and others 2005; Scheiner and Gurevitch 2001). In this context, data from each assessment of suitable patches would be considered a measure. Hierarchical models are also well suited to the data generated by this monitoring protocol because they account for nesting of sites within patches and overcome issues of statistical independence when enough sites are sampled (Snijders and Bosker 1999). Rieman and others (2006) used hierarchical models with samples of 12-20 sites per patch to determine the effects of brook trout invasions on bull trout distributions. Use of hierarchical models with a repeated measures design could provide especially powerful trend detection.

If tissue samples are routinely collected during the course of sampling, a genetic database useful for addressing a range of issues could also be compiled. These issues might include: (1) linkages between landscape or patch characteristics and genetic structure, (2) spatial patterns of hybridization between brook trout and bull trout (e.g., is the hybrid zone expanding with time?), and (3) development of monitoring protocols based on genetic attributes such as effective population size (Schwartz and others 1998). Numerous analyses exist and new ones are rapidly being developed to address these issues in this burgeoning discipline (Manel and others 2003; Schwartz and others 2006). However, genetic analyses

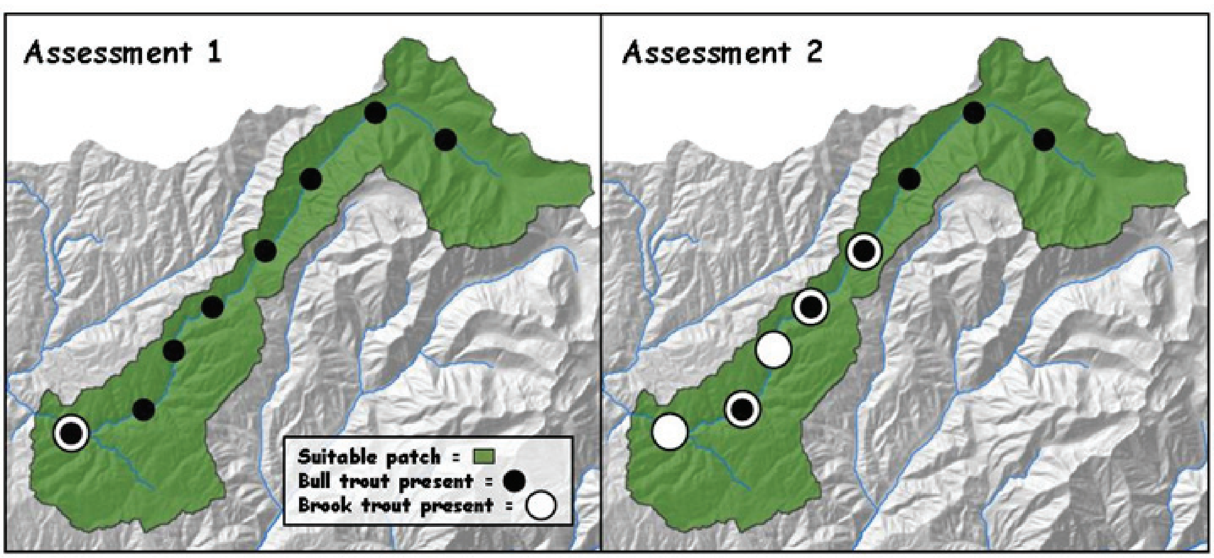


Figure 8. Hypothetical changes in bull trout and brook trout site occupancy within a patch between two assessments.

remain relatively expensive and additional resources or partnerships with entities outside the USFS will often be needed to complete genetic work. Even if resources or immediate plans do not exist, the ease of collection and storage suggests tissue collections should be done whenever possible to preserve future options.

Sentinel Streams

The patch-based monitoring protocol outlined in this report is predicated on the stratification of a monitoring area into suitable and unsuitable habitats. This approach increases efficiency by restricting sampling effort to a subset of habitats, but may miss important changes that occur at or near patch boundaries. Because these areas are transitional between suitable and unsuitable habitats, environmental conditions are likely to be marginal for bull trout and populations weak. As a result, these populations may be especially sensitive to change and could provide early warnings of more systematic changes if detected early.

A simple solution to monitoring patch boundaries entails extension of sample sites downstream from a patch (fig. 9). Site density within the patch should be maintained to achieve the desired detection efficiency, but additional sites are added from the EMAP GRTS master list. Having perhaps 15-20 sites arrayed along the stream from areas suitable for bull trout through unsuitable areas ensures that the patch boundary is covered.

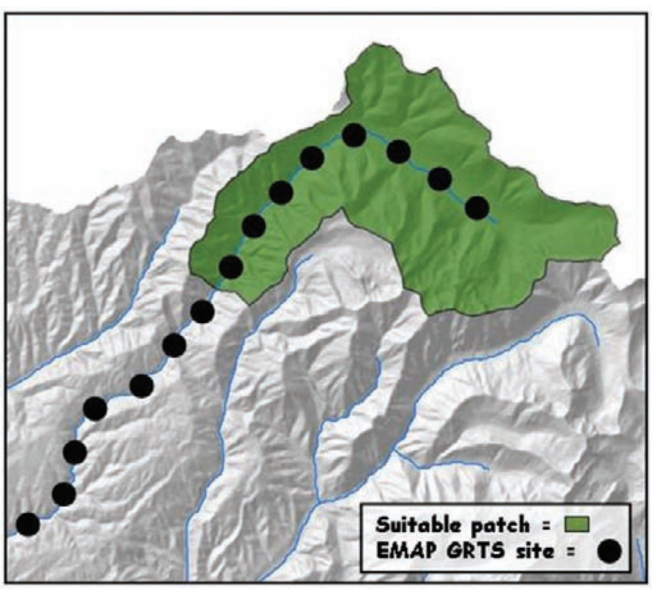


Figure 9. Distribution of sample sites in "sentinel stream" designed to provide inference about population changes in areas near patch boundaries.

Because stream temperature is likely to be associated with any population shifts, it may also be desirable to collect detailed temperature data in these streams.

Sites on these "sentinel streams" could be sampled during each basin-wide assessment or repeated more frequently to provide greater sensitivity to change. Sampling of sentinel streams will require more effort than standard patch surveys, so it may only be possible to monitor a subset of patches in this way. In instances where resources for monitoring are especially limited, managers have expressed interest in using sentinel streams as indicators of basinwide conditions rather than sampling all patches. Good candidates for sentinel status are streams that encompass broad thermal ranges and are relatively easily accessed to facilitate sampling. Other factors to consider may be presence of brook trout, importance of the local bull trout population, and recent management activities or disturbances that are expected to result in patch boundary shifts. Sentinel streams could be located at opposite extremities of a basin or in contrasting geomorphic settings to capture a diversity of potential responses. Analyses of trends in sentinel streams would be similar to those described in the previous section (i.e., repeated measures and hierarchical designs).

Section VIII: Secesh River Watershed Pilot Project

To demonstrate the application of this protocol, a pilot project was initiated in the Secesh River Watershed (SRW) in central Idaho in 2006. The SRW was selected because of its manageable size (64,000 ha), relative ease of access, and generally good habitat conditions for bull trout (Burns and others, unpublished paper; Watry and Scarnecchia 2008). Most (99%) of the basin is administered by the Payette National Forest (PNF), 0.4% is state owned, and 0.6% is privately owned. The downstream end of the SRW is accessible by Forest Highway 48, upstream areas are accessed by Forest Highway 21 and Forest Road 246, and Interior areas are accessible only by trail (fig. 10). Recent fires burned across western portions of the drainage in 1994 and Grouse Creek in 2000. Fires associated with the East Zone Complex burned most of the eastern half of the watershed in 2007.

Spawning and rearing habitat occurs throughout the SRW and migratory (fluvial and/or adfluvial) bull trout are known to ascend Pete Creek and Threemile Creek, and Loon Lake supports an adfluvial population (Watry and Scarnecchia 2008). Two weirs are run by the Nez Perce Tribe, one on the Secesh River near Chinook Campground and one in Lake Creek just above the confluence with Summit Creek. Previous PNF fish survey records document occurrence of bull trout in other areas of the basin, but characteristics and current status are less well known (Appendix A; fig. A1). Brook trout are widely distributed throughout the SRW, supported in some areas by headwater lake populations, and perceived to be one of the largest threats to bull trout persistence (Appendix A; fig. A2).

Methods

Patch delineation

Suitable bull trout habitats were delineated by first modeling the stream network from a DEM using TauDEM (Tarboton 2004), which also determined watershed contributing area, elevation, and stream slope values for all segments of the network. The network was filtered to exclude segments with stream slopes >15% or contributing areas <400 ha (fig. 11). In July of 2006, 51 thermographs were placed throughout this reduced stream network across a range of elevations and contributing areas—two environmental gradients that are strongly related to stream temperature (fig. 12). Temperature data were recovered from these sites in September, checked for errors, and metrics for MWMT and summer mean summarized for the period from July 15 to September 15. These temperature metrics were used as the response variables in multiple regression models. The attributes associated with the TauDEM stream network (e.g., elevation, contributing area, stream slope) were used as predictors. These regression models also included class variable predictors to account for: (1) Loon Lake's warming of downstream temperatures, (2) the effects of the 2000 fires on stream temperatures in Grouse Creek,

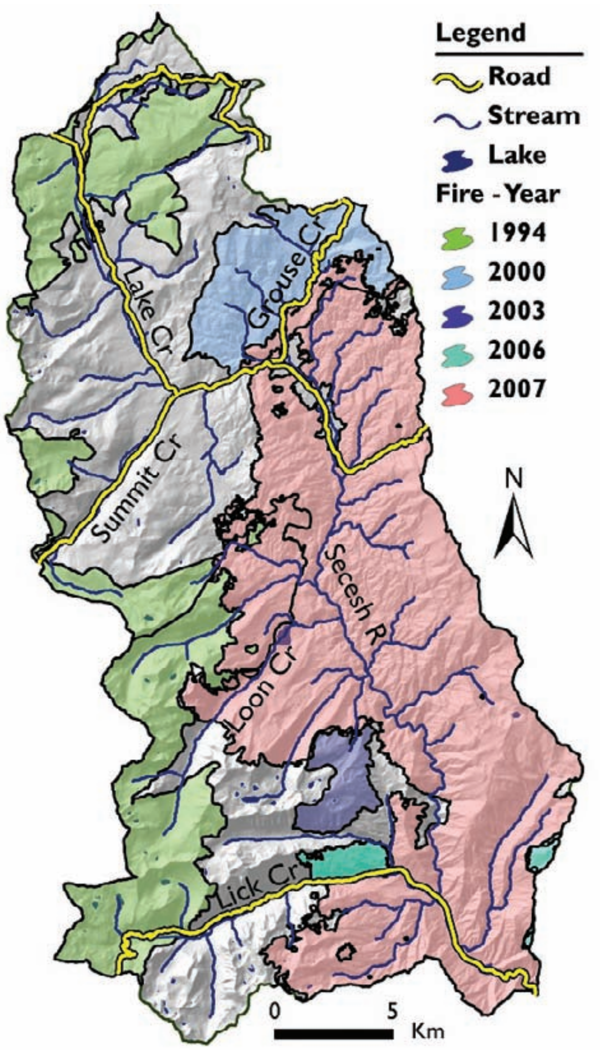


Figure 10. Stream network and other notable features in the Secesh River Basin.

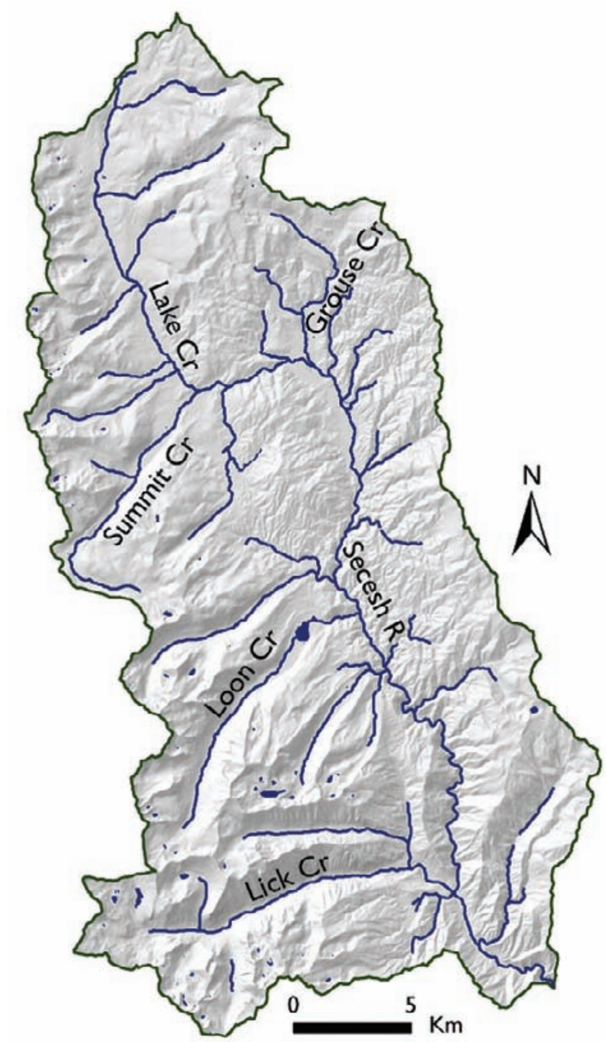


Figure 11. Stream network within the Secesh River Basin filtered to exclude segments steeper than 15% slope or contributing areas <400 ha.

and (3) anomalously warm stream temperatures in Lake Creek, for which the cause was unknown (Appendix A; fig. A3). Regression models predicting stream MWMT and summer mean temperature from these attributes accounted for 61% and 74% of variation, respectively, and are summarized as follows:

$$\text{MWMT} = 18.79 - 0.00186*\text{Elevation} + 0.000184*\text{CA} - 19.8*\text{Slope} + 6.45*\text{Loon Lake} + 2.84*\text{Fire} + 2.25*\text{Lake Creek} \quad (3)$$

$$\text{Mean} = 15.83 - 0.00321*\text{Elevation} + 0.0000706*\text{CA} - 11.5*\text{Slope} + 6.37*\text{Loon Lake} + 1.22*\text{Fire} + 1.19*\text{Lake Creek} \quad (4)$$

Detailed methods for development of stream temperature models and patches are online at http://www.fs.fed.us/rm/boise/AWAE/projects/stream_temperature.shtml

Predictions from these models were used to map stream temperatures prior to the 2007 fires for all segments within the reduced stream network. A relatively liberal temperature criterion of MWMT ≤17.5 °C was chosen to represent thermally suitable habitat patches (fig. 13). Patch delineations based on other temperature criteria are summarized in Appendix A (figs. A4, A5, and A6). Twenty-four bull trout patches were delineated, which generally coincided with major tributaries downstream to their confluences with the Secesh River. An exception was the North Fork Lick Creek, which was considered a separate patch above a high slope segment believed to be a barrier to fish migration upstream from the confluence with Lick Creek. The 24 patches contained 267 km of suitable habitat and represented a 63% reduction from the 720 km shown

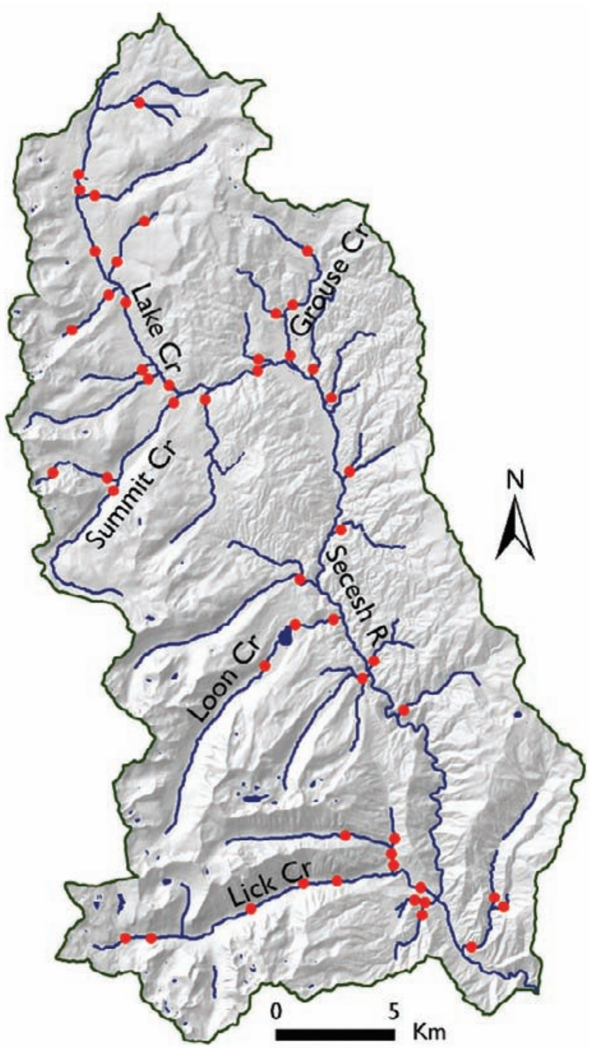


Figure 12. Distribution of thermographs in 2006. Locations were selected to encompass a range of elevations and contributing areas.

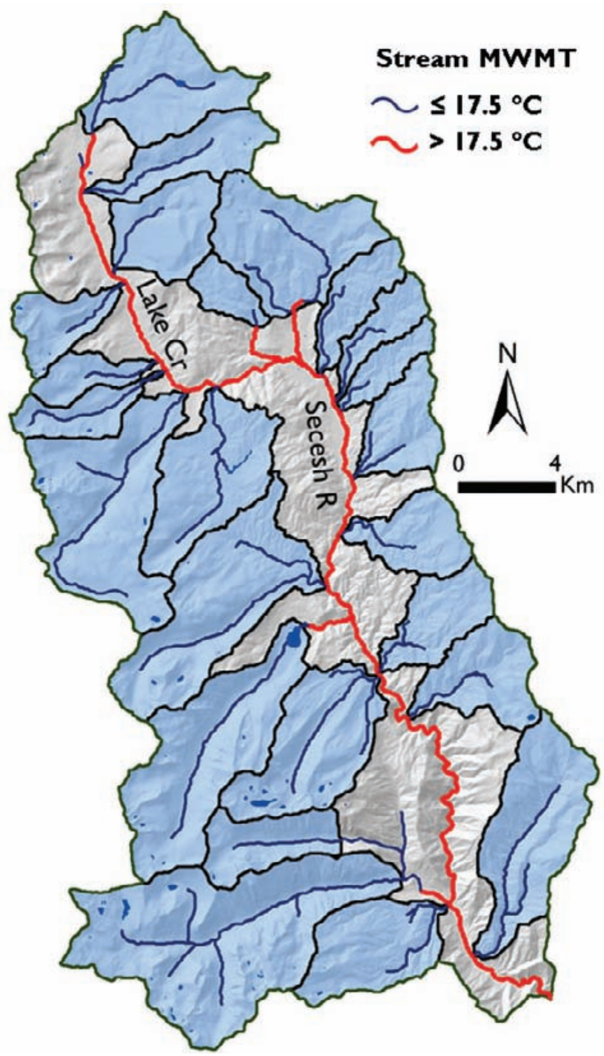


Figure 13. Patches of thermally suitable bull trout habitat within the Secesh River Basin before the 2007 fires based on MWMT ≤17.5 °C. Stream temperatures were predicted from multiple regression models built with data gathered in 2006.

on USGS 1:24,000-scale hydrologic coverages. In the future, bull trout patch delineations may be improved through application of more detailed temperature models with better predictive ability or collection of additional data. Annual monitoring of stream temperatures from locations sampled in 2006, or a subset of these areas, would provide useful descriptions of interannual variation related to air temperatures and stream flow. These factors could be included as additional predictor variables in existing stream temperature models, which would make the models more flexible and provide a means of examining short-term variation in patch boundaries or the ability to accommodate longer-term trends that might arise in relation to climate warming.

Site selection and sampling

Random sites on the stream network were identified using the EMAP GRTS design (Appendix A; fig. A7). To ensure that a sufficient number of potential sites were available within each patch, the standard EMAP sample site density (1 site/km) was increased by a factor of three. This provided an average of 25 ± 17 (SD) potential sample sites within the 24 patches, of which the first 10 sites were selected based on the unique EMAP identifier. It was determined that eight sites would be sampled within a patch based on an assumed detection efficiency of 0.3, which should have reduced the chance of a false absence (i.e., bull trout present but not detected) to ~5% (fig. 6). Two alternative sites were provided in the event that sampling was impossible in one or more of the first eight sites (e.g., access was impossible or dangerous, stream was dry). Sample site locations were uploaded to GPS units to enable accurate field navigation.

U.S. Forest Service, Rocky Mountain Research Station (RMRS) and Payette National Forest (PNF) biologists met at Burgdorf Guard Station on September 5, 2007, to test field protocols and collect preliminary data. Fire activity limited access to much of the watershed, but streams in the Lake Creek and Summit Creek drainages were accessible. Field crews navigated to sites in accessible patches and made single electrofishing passes through ~30m of stream. All salmonids were netted, visually identified to species, measured, and released. Fin clips were taken from bull trout and archived for future genetic assessments. Field crews also took instantaneous measurements of stream temperature with handheld thermometers, measured reach length and width, and counted pieces of LWD.

Results and Discussion

Three two-person crews worked 4 days and sampled 64 sites in eight patches. Bull trout and brook trout were detected in all patches, with the greatest frequencies of bull trout occurring in Pete Creek and Threemile Creek (fig. 14; table 2). Weak bull trout populations were detected in Willow Creek and upper Lake Creek, where single juveniles were captured at single sites. Brook trout were abundant and often dominated species composition in downstream areas (fig. 15). Bull trout in the SRW appeared to be restricted to colder stream temperatures and higher elevations than was the case in other Idaho streams (Appendix A; fig. A8), perhaps a result of the extensive brook trout populations in the SRW. When present, bull trout occurred at densities similar to other systems. Additional summaries of bull trout and brook trout populations relative to site covariates are provided in Appendix A (figs. A9-A15).

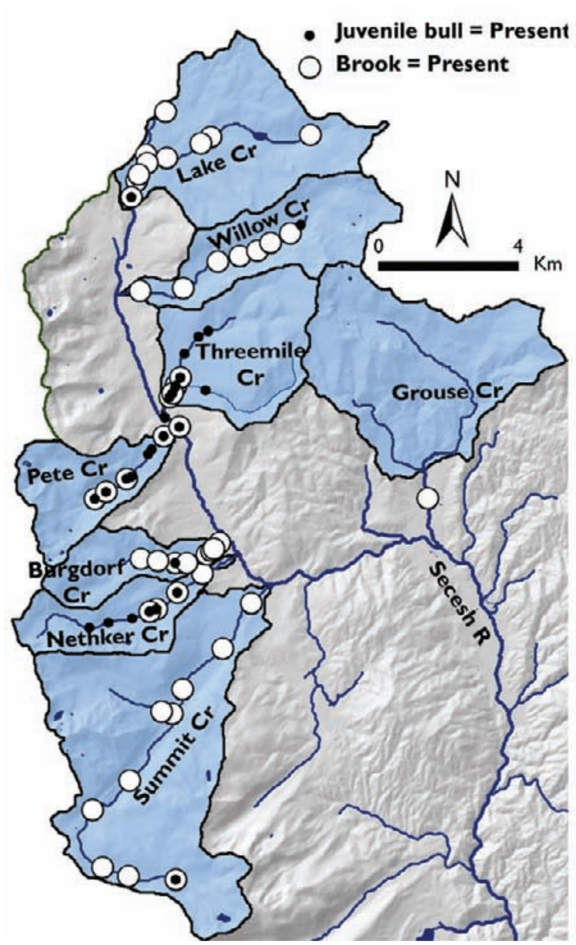


Figure 14. Bull trout and brook trout occurrence at EMAP GRTS sites sampled within eight bull trout patches in the upper Secesh River Watershed.

Table 2—Summary of electrofishing surveys conducted in the Secesh River Watershed from Sept. 6 to 9. Sampling was conducted with single pass electrofishing through 20 to 40 meters of stream. Detection frequencies were calculated based on occurrence of small bull trout (<150 mm).

Stream	Sites sampled	Sites brook trout detected	Sites bull trout detected	% sites bull trout detected
Lake Cr.	10	10	1	10%
Willow Cr.	8	7	1	13%
Threemile Cr.	10	5	10	100%
Pete Cr.	8	5	8	100%
Burgdorf Cr.	8	8	1	13%
Nethker Cr.	7	4	6	86%
Grouse Cr.[a]	3	1	0	—
Summit Cr.	10	10	1	10%
				Mean = 47%

[a]Sampling aborted due to fire activity.

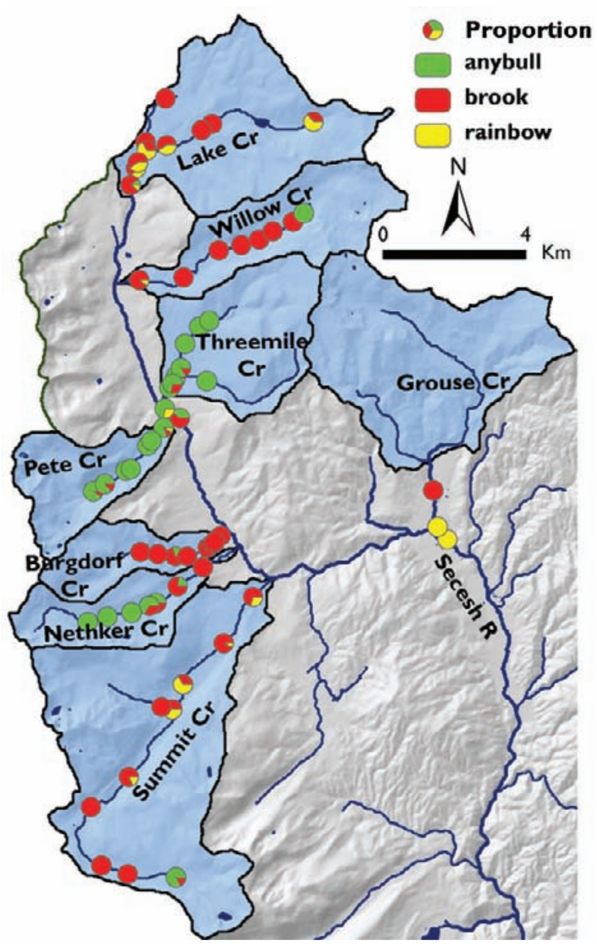


Figure 15. Species composition at EMAP GRTS sites sampled within eight bull trout patches in the upper Secesh River Watershed.

Detection probability

A naïve estimate of bull trout detection probability based on these data is $p_{Secesh} = 0.47$ (table 2), which is higher than estimates derived from similar stream surveys conducted by RMRS in 1997 and 2007 (0.36-0.39; D. Isaak, unpublished data; Rieman and others 2006). Many of the RMRS surveys, however, encompassed a broader thermal range, which would be expected to result in a lower frequency of bull trout detections. The variation in p (0.10-1.00) observed among patches in the Secesh suggests local conditions strongly affect detection and occurrence and future sampling designs could be improved if relationships with important covariates were modeled.

Cost estimates

Crews averaged sampling 5.5 sites/day and required 12 two-person crew days (3 crews x 4 days) to sample 64 sites in eight patches. This accounted for 1/3 of the patches in the basin, so by extrapolation, 24 two-person crew days would be required to finish an initial assessment of the SRW. However, access to many of the remaining patches is difficult, will require extensive hiking or pack animals, and sampling rates are likely to decrease. A more conservative cost estimate that accounts for a wider range of logistical considerations (travel among and within watersheds) can be derived from work that RMRS crews did throughout the summer of 2007. Inclusive of the SRW sampling, these two two-person crews surveyed 230 reaches in 20 patches throughout central

Idaho. Sampling was conducted during five pay periods (40 days) and crews averaged 2.9 sites/day. Assuming a sampling rate intermediate between 2.9 and 5.5 sites/day, a two-person crew would require approximately 2 days/patch (assuming eight sites/patch) and could sample three to four patches/pay period.

Section IX: Conclusion

The SRW pilot project demonstrates the utility and relative ease with which this monitoring protocol can be applied. Some effort and basic GIS skills are needed for initial delineation of suitable habitat patches and sample sites, but this task is done only once, unless patch delineations are later refined with improved temperature data. Stratification of the landscape into suitable and unsuitable habitats can significantly reduce the length of stream that requires sampling, although reductions may be less dramatic in more northerly portions of the bull trout range where stream temperatures are generally cooler. Site survey protocols within suitable patches are designed to quickly extract useful information on bull trout distributions, abundance, and community composition.

Assuming future resources for monitoring continue to be scarce, another strength of the protocol is its compatibility with other databases. Multiple techniques can provide information to address the fundamental question of whether a patch is occupied. Depending on the intensity of recent local sampling by USFS and other agencies, a significant number of patches might be considered occupied during an initial assessment and would not require sampling. During subsequent assessments, or where existing data do not initially confirm occupancy, sampling of patches using methods outlined in this protocol will be needed. As the number of these samples increases, models predicting occurrence and detection could be constructed or power analyses conducted to optimize and refine future sampling efforts. If other agencies or forests adopt similar monitoring protocols (e.g., USFWS 2008b), then larger, regional pools of data may also become available to advance bull trout monitoring efforts.

References

Adams, S. B.; Frissell, C. A.; Rieman, B. E. 2000. Movements of nonnative brook trout in relation to stream channel slope. Transactions of the American Fisheries Society. 129: 623-638.

Al-Chokhachy, R.; Budy, P.; Schaller, H. 2005. Understanding the significance of redd counts: a comparison between two methods for estimating the abundance of and monitoring bull trout populations. North American Journal of Fisheries Management. 25: 1505-1512.

Benjamin, J. R.; Dunham, J. B.; Dare, M. R. 2007. Invasion by nonnative brook trout in Panther Creek, Idaho: roles of local habitat quality, biotic resistance, and connectivity to source habitats. Transactions of the American Fisheries Society. 136: 875-888.

Burns, D.; Faurot, M.; Hogen, D.; McGee, M.; Nelson, R.; Olson, D.; Wagoner, L.; Zurstadt C. 2005. Bull trout populations on the Payette National Forest. Unpublished paper on file at: U.S. Department of Agriculture, Forest Service, Payette National Forest, McCall, ID.

Calabrese, J. M.; Fagan, W. F. 2004. A comparison-shopper's guide to connectivity metrics. Frontiers in Ecology and the Environment. 2: 529-536.

Clarke, S. E.; Burnett, K. M.; Miller, D. J. 2008. Modeling streams and hydrogeomorphic attributes in Oregon from digital and field data. Journal of the American Water Resources Association. 44: 459-477.

Dunham, J.; Chandler, G.; Rieman, B.; Martin, D. 2005. Measuring stream temperature with digital data loggers: a user's guide. RMRS-GTR-150WWW. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 15p.

Dunham, J. B.; Rieman, B. E. 1999. Metapopulation structure of bull trout: influences of physical, biotic, and geometrical landscape characteristics. Ecological Applications. 9: 642-655.

Dunham, J.; Rieman, B.; Chandler, G. 2003a. Influences of temperature and environmental variables on the distribution of bull trout within streams at the southern margin of its range. North American Journal of Fisheries Management. 23: 894-904.

Dunham, J. B.; Rieman, B. E.; Davis, K. 2001. Sources and magnitude of sampling error in redd counts for bull trout. North American Journal of Fisheries Management. 21: 343-352.

Dunham, J. B.; Rosenberger, A. E.; Luce, C. H.; Rieman, B. E. 2007. Influences of wildfire and channel reorganization on spatial and temporal variation in stream temperature and the distribution of fish and amphibians. Ecosystems. 10: 335-346.

Dunham, J. B.; Young, M. K.; Gresswell, R. E.; Rieman, B. E. 2003b. Effects of fire on fish populations: landscape perspectives on persistence of native fishes and nonnative fish invasions. Forest Ecology and Management. 178: 183-196.

Fausch, K. D.; Hawkes, C. L.; Parsons, M. G. 1988. Models that predict standing crop of stream fish from habitat variables: 1950-1985. PNW-GTR-213. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Fleishman, E.; Ray, C.; Sjogren-Gulve, P.; Boggs, C. L.; Murphy, D. D. 2002. Assessing the roles of patch quality, area, and isolation in predicting metapopulation dynamics. Conservation Biology. 16: 706-716.

Fraser, N. H. C.; Metcalfe, N. B.; Thorpe, J. E. 1993. Temperature-dependent switch between diurnal and nocturnal foraging in salmon. Proceedings: Biological Sciences. [Online]. 252(1334): 5 p. Available: http://www.jstor.org/stable/49643 [January 21, 2009].

Fredenberg, W.; DeHaan, P.; Ardren, W. 2007. Genetic analysis and photo documentation of hybridization between bull trout and brook trout in the Swan River basin, Montana. Prepared for: Swan Valley Bull Trout Working Group.

Gamett, B. L. 2002. The relationship between water temperature and bull trout distribution and abundance. Master's thesis. Utah State University, Logan.

Gavin, D. G.; Hallett, D. J.; Hu, F. S.; Lertzman, K. P.; Prichard, S. J.; Brown, K. J.; Lynch, J. A.; Bartlein, P.; Peterson, D. L. 2007. Forest fire and climate change in western North America: insights from sediment charcoal records. Frontiers in Ecology and the Environment. 5: 499-506.

Gende, S. M.; Edwards, R. T.; Willson, M. F.; Wipfli, M. S. 2002. Pacific salmon in aquatic and terrestrial ecosystems. Bioscience. 52: 917-928.

Guisan, A.; Broennimann, O.; Engler, R.; Vust, M.; Yoccoz, N. G.; Lehmann, A.; Zimmermann, N. E. 2006. Using niche-based models to improve the sampling of rare species. Conservation Biology. 20: 501-511.

Ham, K. D.; Pearsons, T. N. 2000. Can reduced salmonid population abundance be detected in time to limit management impacts? Canadian Journal of Fisheries and Aquatic Sciences. 57: 17-24.
Hamlet, A. F.; Lettenmaier, D. P. 2007. Effects of 20th century warming and climate variability on flood risk in the Western U.S. Water Resources Research 43, W06427, doi:10.1029/2006WR005099
Hanksi, I. A. 1999. Metapopulation ecology. Oxford University Press, Oxford.
Hillman, T. W.; Essig, D. 1998. Review of bull trout temperature requirements: a response to the EPA bull trout temperature rule. Unpublished report prepared for Idaho Department of Environmental Quality. Bioanalysts, Inc., Boise, ID. 69p.
Intergovernmental Panel on Climate Change (IPCC). 2007. Climate change 2007: the physical science basis. [Online]. http://www.ipcc.ch/ [January 21, 2009].
Isaak, D. J. 2007. Unpublished data on file at Rocky Mountain Research Station, Boise, ID.
Isaak, D. J.; Hubert, W. A. 2001. A hypothesis about factors that affect maximum summer stream temperatures across montane landscapes. Journal of the American Water Resources Association. 37: 351-366.
Isaak, D. J.; Hubert, W. A.; Krueger, K. L. 1999. Accuracy and precision of stream reach water surface slopes estimated in the field and from maps. North American Journal of Fisheries Management. 19: 141-148.
Isaak, D. J.; Thurow, R. F. 2006. Network-scale spatial and temporal variation in Chinook salmon redd distributions: patterns inferred from spatially continuous replicate surveys. Canadian Journal of Fisheries and Aquatic Sciences. 63: 285-296.
Isaak, D. J.; Thurow, R. F.; Rieman, B. E.; Dunham, J. B. 2003. Temporal variation in synchrony among Chinook salmon redd counts from a wilderness area in central Idaho. Canadian Journal of Fisheries and Aquatic Sciences. 60: 840-848.
Isaak, D. J.; Thurow, R. F.; Rieman, B. E.; Dunham, J. B. 2007. Relative roles of habitat quality, size, and connectivity in Chinook salmon use of spawning patches. Ecological Applications. 17: 352-364.
Kanda, N.; Leary, R. F.; Allendorf, F. W. 2002. Evidence of introgressive hybridization between bull trout and brook trout. Transactions of the American Fisheries Society. 131: 772-782.
Kellet, M. 2006. [Pers. comm.]. U.S. Department of Agriculture, Forest Service, Boise National Forest.
Kutner, M. H.; Nachtsheim, C. J.; Neter, J.; Li, W. 2005. Applied linear statistical models, fifth edition. McGraw-Hill Irwin, New York.
MacKenzie, D. I.; Nichols, J. D.; Lachman, G. B.; Droege, S.; Royle, J. A.; Langtimm, C. A. 2002. Estimating site occupancy rates when detection probabilities are less than one. Ecology. 83: 2248-2255.
MacKenzie, D. I.; Nichols, J. D.; Royle, J. A.; Pollock, K. H.; Bailey, L. L.; Hines, J. E. 2006. Occupancy estimation and modeling. Academic Press, New York.
Manel, S.; Schwartz, M. K.; Luikart, G. L.; Taberlet, P. 2003. Landscape genetics: combining landscape ecology and population genetics. Trends in Ecology and Evolution. 18: 189-197.
Maxell, B. A. 1999. A power analysis on the monitoring of bull trout stocks using redd counts. North American Journal of Fisheries Management 19(3): 860-866.
McCleary R. J.; Hassan, M. A. 2008. Predictive modeling and spatial mapping of fish distributions in small streams of the Canadian Rocky Mountain foothills. Canadian Journal of Fisheries and Aquatic Sciences. 65: 319-333.
Mohseni, O.; Stefan, H. G. 1999. Stream temperature/air temperature relationship: a physical interpretation. Journal of Hydrology. 218: 128-141.
Moilanen, A.; Nieminen, M. 2002. Simple connectivity measures in spatial ecology. Ecology. 83: 1131-1145.
Monnot, L.; Dunham, J. B.; Hoem, T.; Koetsier, P. 2008. Influences of body size and environmental factors on autumn downstream migration of bull trout in the Boise River, Idaho. North American Journal of Fisheries Management. 28: 231-240.
Mote P.; Salathé, E.; Peacock, C. 2005. Scenarios of future climate for the Pacific Northwest. Climate Impacts Group, University of Washington.
Neville, H. M.; Dunham, J. B.; Peacock, M. M. 2006. Landscape attributes and life history variability shape genetic structure of trout populations in a stream network. Landscape Ecology. 21: 901-916.
Pellet, J.; Fleishman, E.; Dobkin, D. S.; Gander, A.; Murphy, D. D. 2007. An empirical evaluation of the area and isolation paradigm of metapopulation dynamics. Biological Conservation. 136: 483-495.
Peterson, J. T.; Dunham, J. B. 2003. Combining inferences from models of capture efficiency, detectability, and suitable habitat to classify landscapes for conservation of threatened bull trout. Conservation Biology. 17: 1070-1077.
Peterson, J. T.; Thurow, R. F.; Guzevich, J. W. 2004. An evaluation of multipass electrofishing for estimating the abundance of stream-dwelling salmonids. American Fisheries Society. 133: 462-475.
Platts, W. S.; Megahan, W. F.; Minshall, G. W. 1983. Methods for evaluating stream, riparian, and biotic conditions. USDA Forest Service, Intermountain Research Station, Gen. Tech. Rep. INT-138, Ogden, UT.
Platts, W. S.; Nelson, R. L. 1988. Fluctuations in trout populations and their implications for land-use evaluation. North American Journal of Fisheries Management. 8: 333-345.
Poole, G. C.; Berman, C. H. 2001. An ecological perspective on in-stream temperature: natural heat dynamics and mechanisms of human-caused thermal degradation. Environmental Management. 27: 787-802.
Quinn, T. P. 2005. The behavior and ecology of Pacific salmon and trout. American Fisheries Society, Bethesda, MD.
Rich, C. F.; McMahon, T. E.; Rieman, B. E.; Thompson, W. L. 2003. Local-habitat, watershed, and biotic features associated with bull trout occurrence in Montana streams. Transactions of the American Fisheries Society. 132: 1053-1064.
Richmond, A. D.; Fausch, K. D. 1995. Characteristics and function of large woody debris in subalpine Rocky Mountain streams in northern Colorado. Canadian Journal of Fisheries and Aquatic Sciences. 52: 1789-1802.
Rieman, B. E.; Allendorf, F. W. 2001. Effective population size and genetic conservation criteria for bull trout. North American Journal of Fisheries Management. 21: 756-764.
Rieman, B. E., and Chandler, G. L. 1999. Empirical evaluation of temperature effects on bull trout distribution in the northwest. Final Report to: U.S. EPA, Contract 12957242-01-0, Boise, ID.
Rieman, B. E.; Isaak, D. J.; Adams, S.; Horan, D.; Nagel, D.; Luce, C.; Myers, D. 2007. Anticipated climate warming effects on bull trout habitats and populations across the Interior Columbia River basin. Transactions of the American Fisheries Society 136: 1552-1565.
Rieman, B. E.; Lee, D. C.; Thurow, R. F. 1997. Distribution, status, and likely future trends of bull trout within the Columbia River and Klamath River basins. North American Journal of Fisheries Management. 17: 895-909.
Rieman, B. E.; McIntyre, J. D. 1995. Occurrence of bull trout in naturally fragmented habitat patches of varied size. Transactions of the American Fisheries Society. 124: 285-296.
Rieman, B. E.; Peterson, J. T.; Myers, D. L. 2006. Have brook trout displaced bull trout along longitudinal gradients in central Idaho streams? Canadian Journal of Fisheries and Aquatic Sciences. 63: 63-78.
Running, S. W. 2006. Is global warming causing more, larger wildfires? Science. 313: 927-928.
Scheiner, S. M.; Gurevitch, J. 2001. Design and analysis of ecological experiments, second edition. Oxford University Press, New York.
Schick, R. S.; Lindley, S. T. 2007. Directed connectivity among fish populations in a riverine network. Journal of Applied Ecology. 44: 1116-1126.

Schlosser, I. J. 1991. Stream fish ecology: a landscape perspective. BioScience. 41: 704-712.

Schwartz, M. K.; Luikart, G.; Waples, R. S. 2006. Genetic monitoring as a promising tool for conservation and management. Trends in Ecology and Evolution. 22: 25-33.

Schwartz, M. K.; Tallmon, D. A.; Luikart, G. 1998. Review of DNA-based census and effective population size estimators. Animal Conservation. 1: 293-299.

Snijders, T.; Bosker, R. 1999. Multilevel analysis: an introduction to basic and advanced multilevel modeling. Sage, Thousand Oaks, CA.

Spruell, P.; Bartron, M. L.; Kanda, N.; Allendorf, F. W. 2001. Detection of hybrids between bull trout and brook trout using PCR primers complementary to interspersed nuclear elements. Copeia. 2001: 1093-1099.

Stevens, Jr., D. L.; Olsen, A. R. 2004. Spatially balanced sampling of natural resources. Journal of the American Statistical Association. 99: 262-278.

Stewart, I. T.; Cayan, D. R.; Dettinger, M. D. 2005. Changes toward earlier streamflow timing across western North America. Journal of Climate. 18: 1136-1155.

Tarboton, D. G. 2004. Terrain analysis using digital elevation models (TauDEM). http://hydrology.neng.usu.edu/taudem/

Temple, G. M.; Pearsons, T. N. 2007. Electrofishing: backpack and drift boat. In D. H. Johnson, B. M. Shrier, J. S. O'Neal, J. A. Knutzen, X. Augerot, T. A. O'Neil, and T. N. Pearsons, editors. Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethesda, MD.

Thurow, R. F.; Peterson, J. T.; Guzevich, J. W. 2006. Utility and validation of night snorkel counts for estimating bull trout abundance in first-to-third order streams. North American Journal of Fisheries Management. 26: 117-132.

Thurow, R. F.; Schill, D. J. 1996. Comparison of day snorkeling, night snorkeling, and electrofishing to estimate bull trout abundance and size structure in a second-order Idaho stream. North American Journal of Fisheries Management. 16: 314-323.

Tyre, A. J.; Tenhumberg, B.; Field, S. A.; Niejalke, D.; Parris, K.; Possingham, H. P. 2003. Improving precision and reducing bias in biological surveys: estimating false-negative error rates. Ecological Applications. 13: 1790-1801.

Urban, D.; Keitt, T. 2001. Landscape connectivity: a graph-theoretic perspective. Ecology. 82: 1205-1218.

U.S. Fish and Wildlife Service (USFWS). 1998. Endangered and threatened wildlife and plants; determination of threatened status for bull trout in the Columbia and Klamath River basins; final rule. Federal Register 63: 31647.

U.S. Fish and Wildlife Service (USFWS). 1999. Endangered and threatened wildlife and plants; determination of threatened status for bull trout in the coterminous United States; final rule. Federal Register 64: 58909.

U.S. Fish and Wildlife Service (USFWS). 2002. Bull trout draft recovery plan. [Online]. Available: http://www.fws.gov/pacific/bulltrout/Recovery.html [January 21, 2009].

U.S. Fish and Wildlife Service (USFWS). 2008a. Bull trout 5-year status review: summary and evaluation. Available: http://www.fws.gov/pacific/bulltrout/5yrreview.html [January 21, 2009].

U.S. Fish and Wildlife Service (USFWS). 2008b. Bull trout recovery: monitoring and evaluation guidance. Report prepared for the U.S. Fish and Wildlife Service by the Bull Trout Recovery and Monitoring Technical Group (RMEG). Portland, OR. Version 1. 74p.

Watry, C. B.; Scarnecchia D. L. 2008. Adfluvial and fluvial life history variations and migratory patters of a relict charr, *Salvelinus confluentus*, stock in west-central Idaho, USA. Ecology of Freshwater Fish. 17: 231-243.

Watson, G.; Hillman, T. W. 1997. Factors affecting the distribution and abundance of bull trout: an investigation at hierarchical scales. North American Journal of Fisheries Management. 17: 237-252.

Webb, B. W.; Hannah, D. M.; Moore, R. D.; Brown, L. E.; Nobilis, F. 2008. Recent advances in stream and river temperature research. Hydrological Processes. 22: 902-918.

Westerling, A. L.; Hidalgo, H. G.; Cayan, D. R.; Swetnam, T. W. 2006. Warming and earlier spring increases western U.S. forest wildfire activity. ScienceExpress. 6 July 2006.

Whiteley, A. R.; Spruell, P.; Rieman, B. E.; Allendorf, F. W. 2006. Fine-scale genetic structure of bull trout at the southern limit of their distribution. Transactions of the American Fisheries Society. 135: 1238-1253.

Wintle, B. A.; McCarthy, M. A.; Parris, K. M.; Burgman, M. A. 2004. Precision and bias of methods for estimating point survey detection probabilities. Ecological Applications. 14: 703-712.

Appendix A

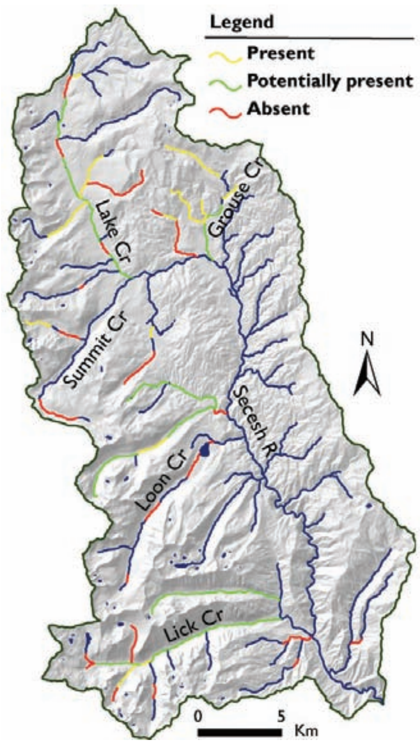


Figure A1. Distribution of bull trout within the Secesh River Watershed based on Payette National Forest records.

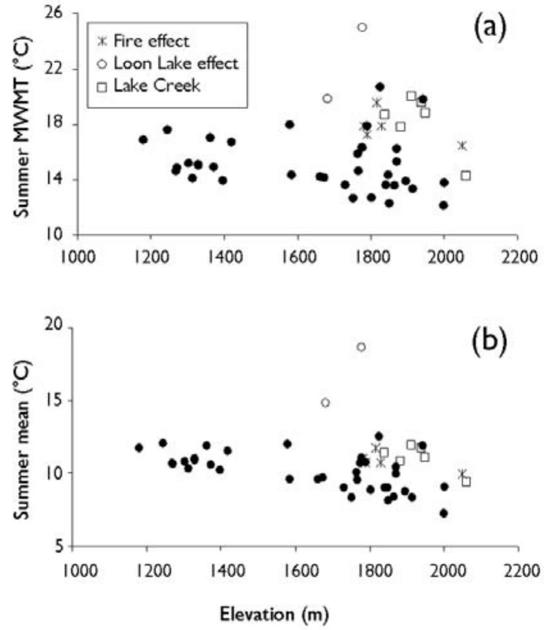


Figure A3. Scatterplots of stream temperature versus elevation within the Secesh River Watershed for summer: (a) MWMT and (b) mean.

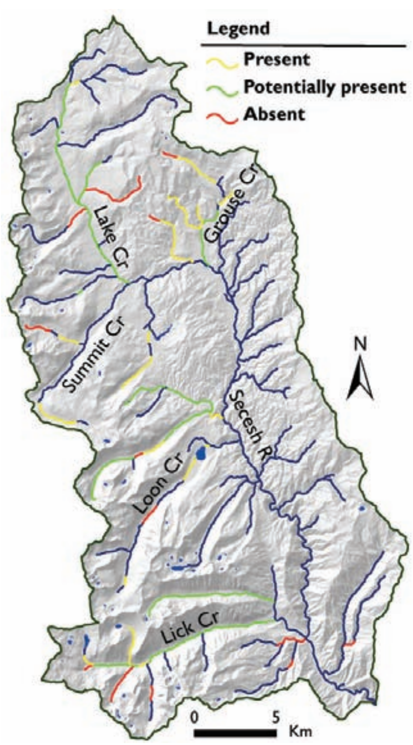


Figure A2. Distribution of brook trout within the Secesh River Watershed based on Payette National Forest records.

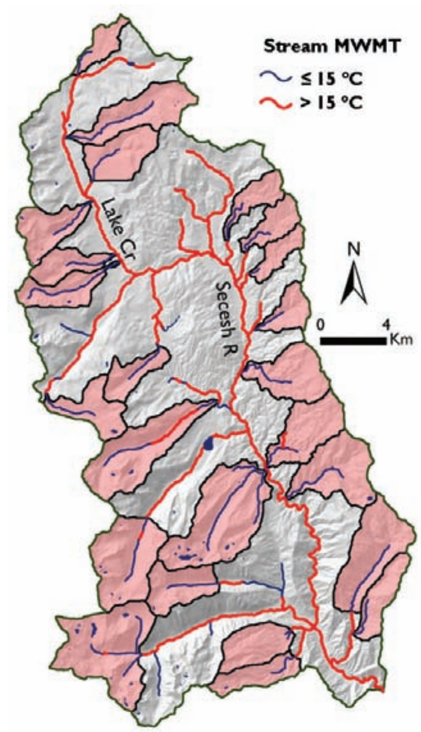


Figure A4. Patches of thermally suitable bull trout habitat within the Secesh River Watershed before the 2007 fires based on conservative (MWMT ≤15 °C) maximum temperature criteria.

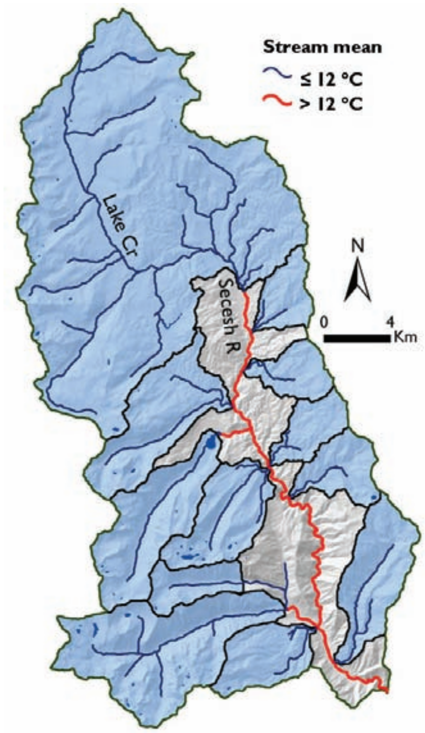


Figure A5. Patches of thermally suitable bull trout habitat within the Secesh River Watershed before the 2007 fires based on liberal (mean ≤12 °C) mean temperature criteria.

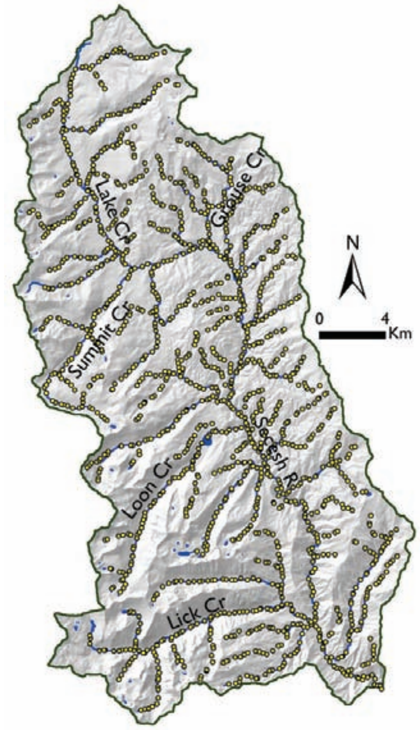


Figure A7. Locations of random sample sites from the EMAP GRTS design for the Secesh River Watershed.

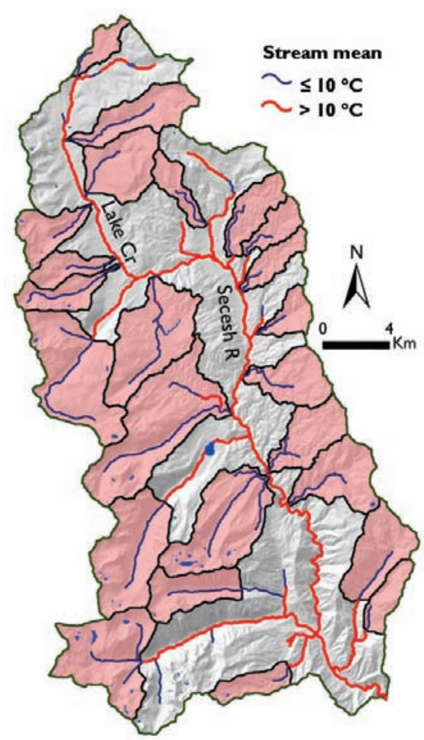


Figure A6. Patches of thermally suitable bull trout habitat within the Secesh River Watershed before the 2007 fires based on conservative (mean ≤10 °C) mean temperature criteria.

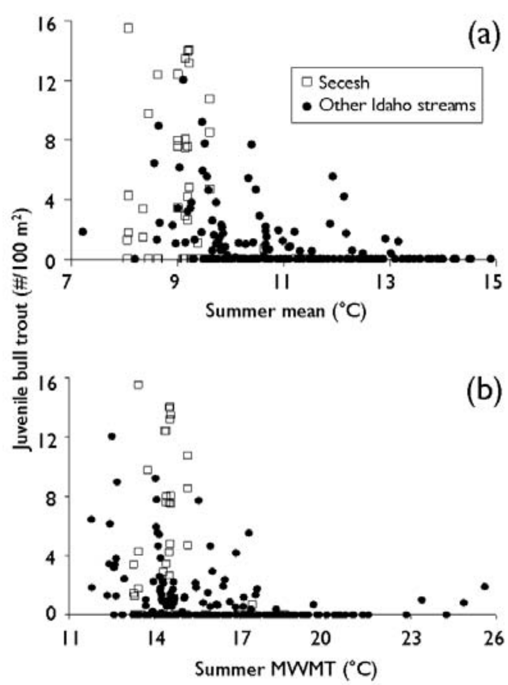


Figure A8. Juvenile bull trout density versus summer mean (panel a) and MWMT (panel b) stream temperatures at 64 sites sampled in the upper Secesh River. Secesh River data are highlighted against data collected using a similar protocol in 12 central Idaho streams (D. Isaak, unpublished data).

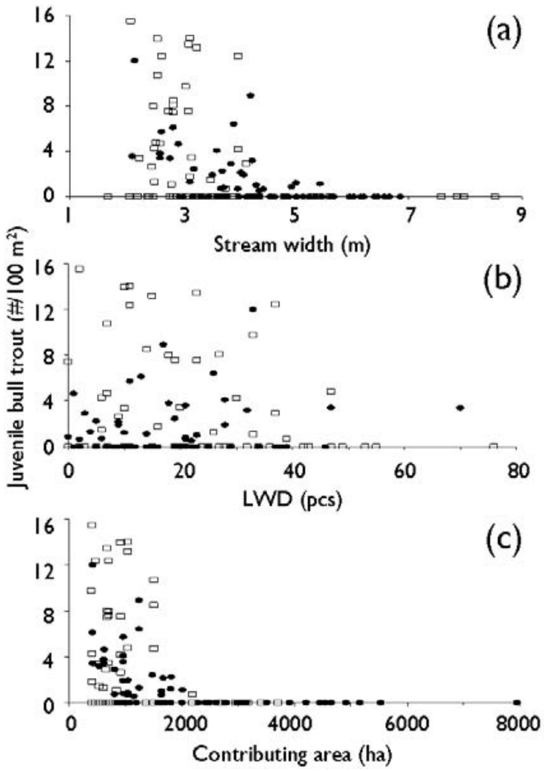


Figure A9. Juvenile bull trout density versus covariates at 64 sites sampled in the upper Secesh River. Panels show relationships with: (a) stream wetted width, (b) large woody debris, and (c) contributing area. Secesh River data (open squares) are highlighted against data collected using a similar protocol in 12 central Idaho streams (dark circles; D. Isaak, unpublished data).

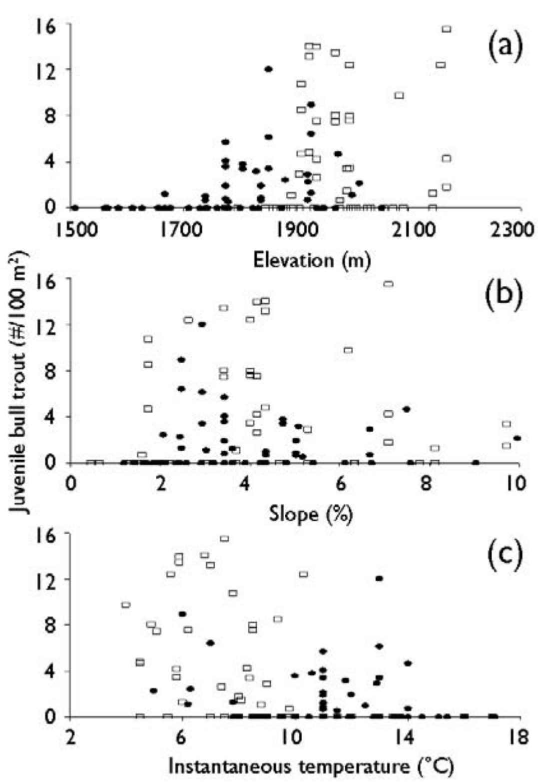


Figure A10. Juvenile bull trout density versus covariates at 64 sites sampled in the upper Secesh River. Panels show relationships with: (a) elevation, (b) slope, and (c) instantaneous stream temperature. Secesh River data (open squares) are highlighted against data collected using a similar protocol in 12 central Idaho streams (dark circles; D. Isaak, unpublished data).

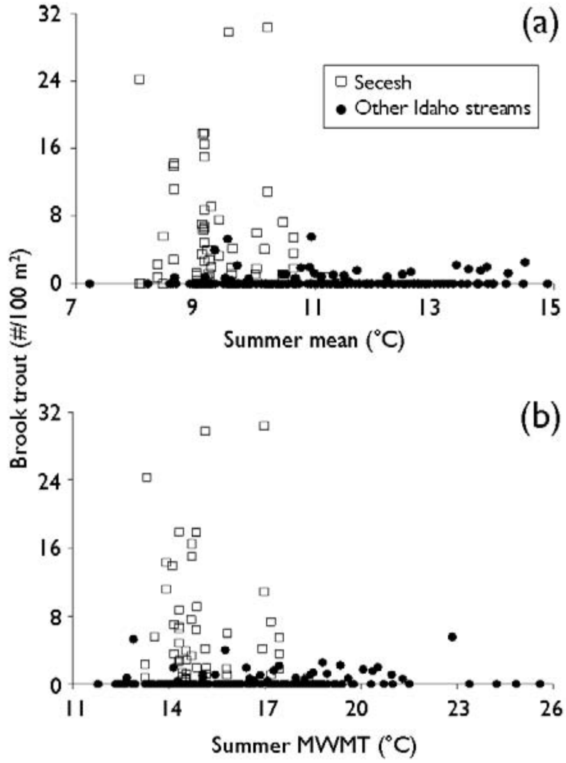


Figure A11. Brook trout density versus summer mean (panel a) and MWMT (panel b) stream temperatures at 64 sites sampled in the upper Secesh River. Secesh River data are highlighted against data collected using a similar protocol in 12 central Idaho streams (D. Isaak, unpublished data).

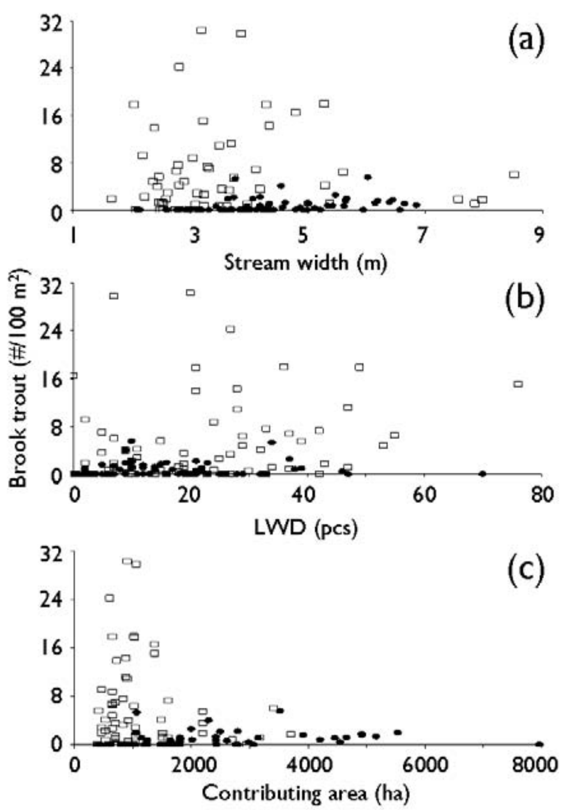


Figure A12. Brook trout density versus habitat covariates at 64 sites sampled in the upper Secesh River. Panels show relationships with: (a) stream wetted width, (b) large woody debris, and (c) contributing area. Secesh River data (open squares) are highlighted against data collected using a similar protocol in 12 central Idaho streams (dark circles; D. Isaak, unpublished data).

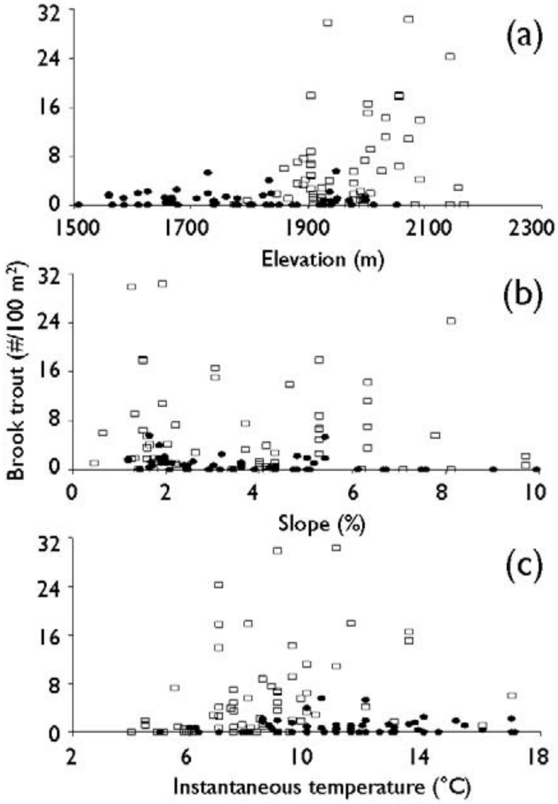


Figure A13. Brook trout density versus habitat covariates at 64 sites sampled in the upper Secesh River. Panels show relationships with: (a) elevation, (b) slope, and (c) instantaneous stream temperature. Secesh River data (open squares) are highlighted against data collected using a similar protocol in 12 central Idaho streams (dark circles; D. Isaak, unpublished data).

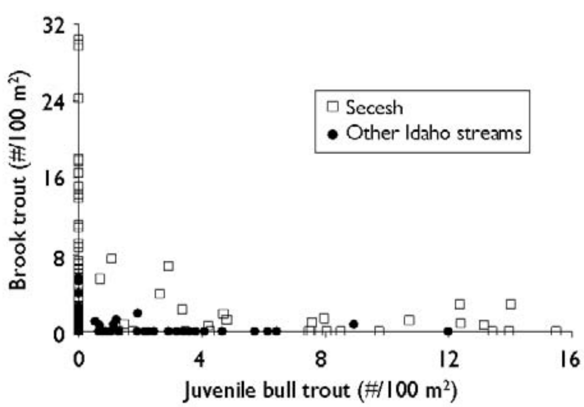


Figure A14. Brook trout density versus bull trout density at 64 sites sampled in the upper Secesh River. Secesh River data (open squares) are highlighted against data collected using a similar protocol in 12 central Idaho streams (dark circles; D. Isaak, unpublished data).

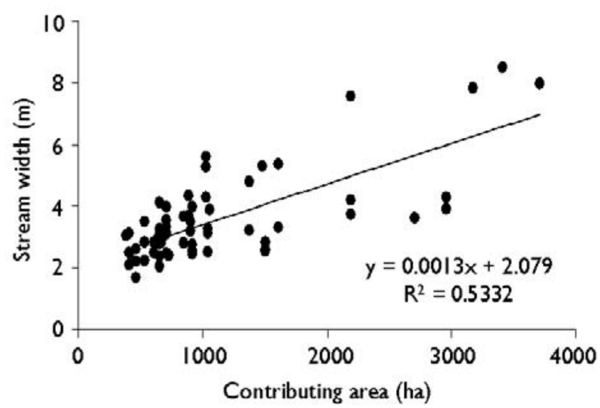


Figure A15. Stream wetted width versus reach contributing area for 64 sites sampled in the upper Secesh River.

The Rocky Mountain Research Station develops scientific information and technology to improve management, protection, and use of the forests and rangelands. Research is designed to meet the needs of the National Forest managers, Federal and State agencies, public and private organizations, academic institutions, industry, and individuals. Studies accelerate solutions to problems involving ecosystems, range, forests, water, recreation, fire, resource inventory, land reclamation, community sustainability, forest engineering technology, multiple use economics, wildlife and fish habitat, and forest insects and diseases. Studies are conducted cooperatively, and applications may be found worldwide.

Station Headquarters
Rocky Mountain Research Station
240 W. Prospect Road
Fort Collins, CO 80526
(970) 498-1100

Research Locations

Flagstaff, Arizona
Fort Collins, Colorado
Boise, Idaho
Moscow, Idaho
Bozeman, Montana
Missoula, Montana
Reno, Nevada
Albuquerque, New Mexico
Rapid City, South Dakota
Logan, Utah
Ogden, Utah
Provo, Utah

Federal Recycling Program Printed on Recycled Paper