FEASIBILITY ASSESSMENT FOR TRANSLOCATION OF IMPERILED BULL TROUT POPULATIONS IN GLACIER NATIONAL PARK, MONTANA

by

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A thesis submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Fish and Wildlife Management

MONTANA STATE UNIVERSITY
Bozeman, Montana

January 2014

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ACKNOWLEDGMENTS

This research was conducted in cooperation with the US Geological Survey, the US Fish and Wildlife Service, the National Park Service, the Montana Cooperative Fisheries Research Unit, and Montana State University. I would first like to thank Dr. Clint Muhlfeld for providing me the opportunity to conduct this research and endless support throughout my graduate experience. Many thanks also to Dr. Christopher Guy, who served as my graduate advisor and provided guidance throughout the research process. Thank you also to Dr. Wyatt Cross, who served as a member on my graduate committee. A special thanks to my one-man field crew Tommy Pederson for his unwavering hard work and positive attitude. Thanks also to Vin D'Angelo, Brady Miller, Carter Fredenberg, Chris Downs, and Ali White for logistical and field assistance. I must also thank my family for their support throughout my graduate career. A very special thank you to my wife Tori for believing in me and encouraging me through all the difficult times.

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ABSTRACT

Translocations are becoming an important tool for conservation and recovery of native fishes. However, many translocations have been unsuccessful likely due to inadequate feasibility assessments of abiotic and biotic factors influencing translocation success prior to implementation. This study provides a framework developed to assess the feasibility of translocating threatened bull trout *Salvelinus confluentus* into novel stream and lake systems in Glacier National Park, Montana (GNP). Populations of bull trout in GNP are at risk of extirpation in several lakes due to the establishment of nonnative invasive lake trout *S. namaycush*. Drainage-specific translocations of extant bull trout populations have been proposed as a possible management solution to these declines, but the suitability of translocation sites is unknown. This study evaluated the suitability of spawning, rearing, foraging, and overwintering habitats in three isolated headwater stream and lake systems (Logging, Camas, and Lincoln sites) to determine their suitability for bull trout translocation. A scoring framework was developed to compare the suitability of proposed translocation sites based on three major components: potential for the recipient habitat to support a translocation; potential for the translocation to negatively impact native aquatic biota; and ability of within-drainage donor populations to support a translocation. Scoring criteria were developed based on abiotic and biotic characteristics known to influence translocation success, including water temperature, habitat quantity and quality, habitat complexity, species composition, and the possibility of conducting within-drainage translocation. Based on the framework, the Camas site is the most suitable for translocation because it contains physical and biological conditions comparable to other systems supporting bull trout. The Logging site is the second most suitable site for translocation, whereas the Lincoln site is least suitable because it contains a minimal amount of stream habitat (< 300 m) and nonnative brook trout. These results will be used to prioritize and plan potential translocation strategies for imperiled bull trout populations in GNP and provide a framework for evaluating the feasibility of conducting translocations elsewhere.

INTRODUCTION

The major threats to the planet's biodiversity are pollution, habitat loss, over-exploitation, invasive species, and climate warming (Richter et al. 1997; Novacek and Cleland 2001; IUCN 2007). The current species extinction rate is estimated between 1,000 and 10,000 times the natural background extinction rate (IUCN 2007). Freshwater aquatic species are experiencing one of the highest extinction rates of any class of animal (Burkhead 2012). Current extinction rates for freshwater fauna are similar to those of tropical rainforest communities (Ricciardi and Rasmussen 1999). An estimated one to eight percent of all freshwater species are thought to go extinct every decade (Reid 1997).

Freshwater aquatic species are most at risk from habitat loss and invasive species (Richter et al. 1997; IUCN 2007). Introductions of nonnative fishes have homogenized native fish faunas across the United States (Rahel 2000), and have been identified as a major factor contributing to the extinction of at least 27 species of freshwater fishes in North America between 1889 and 1989 (Miller et al. 1989). Forty percent of North American freshwater fish species were listed as endangered, threatened, or of special concern by 2008 (Jelks et al. 2008).

Species Translocations

Several strategies have been developed to conserve threatened species and populations at risk of extinction. These approaches include conserving and restoring critical habitat, limiting pollution, imposing strict harvest regulations, establishing captive breeding programs, supplementing wild populations, and establishing new populations

through translocation (IUCN 2007). Translocation is defined as the intentional movement of individuals from one area to another in an attempt to establish or re-establish self-sustaining populations of a target species (IUCN 1998), and includes introductions, reintroductions, and re-stockings (IUCN1987).

Multiple strategies have proven successful at conserving native species. For example, a combination of captive breeding and reintroductions were successful in preventing the extinction of the California condor *Gymnogyps californianus* (Ralls and Ballou 2004). Reintroductions were also used as the main tool to reestablish gray wolf *Canis lupis* populations in the northern Rocky Mountains, USA (Fritts et al. 1997). Translocation has been successful for many other animal species, including white rhino *Ceratotherium simum*, southern sea otter *Enhydra lutris neries*, and bighorn sheep *Ovis canadensis* (Jameson et al. 1982; Bleich et al. 1990; Emslie et al. 2009).

Successful translocations of freshwater fish species have been documented in western North America. For example, four of five translocations of Gila trout *Oncorhynchus gilae* conducted prior to 1992 were successful at establishing self-sustaining populations (Propst et al. 1992). Translocations of Bonneville cutthroat trout *O. clarkii utah* were successful in five of six translocation attempts prior to 1997 (Hepworth et al. 1997). Furthermore, translocation has been used as a recovery tool for the greenback cutthroat trout *O. clarkii stomias* and more recently the humpback chub *Gila cypha* (Harig et al. 2000; NPS 2011).

Other translocation attempts have failed to establish self-sustaining populations of the target species. For example, 23 of 37 translocation attempts of greenback cutthroat

trout prior to 1991 failed to establish self-sustaining populations (Harig et al. 2000). Additionally, translocations of Gila topminnow *Poeciliopsis occidentalis* failed at 31 of 58 sites conducted prior to 1983 (Brooks 1985). Failures of translocation attempts are attributed to many causes, including invasion of nonnative species, unsuitable habitat conditions, competition with existing species, flood events, and other unfavorable environmental factors (Brooks 1985; Propst et al. 1992; Harig et al. 2000).

Threatened Bull Trout

Biologists are currently considering within-drainage translocation as a tool to conserve imperiled bull trout *Salvelinus confluentus* populations west of the Continental Divide in Glacier National Park (GNP), Montana, USA. The bull trout is listed as a threatened species under the U.S. Endangered Species Act (ESA), and is listed as threatened in parts of Canada (USFWS 1998; COSEWIC 2012). Historically, bull trout occurred throughout the Columbia River Basin, east of the Continental Divide in the Saint Mary and Belly River drainages in Montana, south to the Jarbidge River in northern Nevada, the Klamath Basin in Oregon, the McCloud River in California, and north to Alberta and British Columbia (USFWS 1998). To date, the bull trout is extirpated in California, and many populations are at risk of extirpation elsewhere, primarily due to habitat degradation, habitat fragmentation, invasive species, and climate warming (Rieman et al. 1997; USFWS 1998; Rieman et al. 2007).

Adfluvial bull trout currently inhabit approximately 100 lakes within the USA, of which only half are natural, undammed systems (Fredenberg et al. 2007; Meeuwig and

Guy 2007). Glacier National Park supports approximately one third of the remaining natural lake habitat for adfluvial bull trout in the United States, including five of the 15 lakes larger than 350 ha (Fredenberg et al. 2007; Meeuwig and Guy 2007). Research has shown bull trout populations have been declining in western GNP over the past several decades, resulting from the invasion of nonnative lake trout *Salvelinus namaycush* (Fredenberg 2002; Meeuwig et al. 2008; Downs et al. 2011; D'Angelo and Muhlfeld 2013).

Lake Trout Effects on Bull Trout

Many remaining bull trout populations in western GNP are at risk of extirpation due to the invasion and establishment of nonnative lake trout (Fredenberg 2002; Meeuwig et al. 2008). The U.S. Fish Commission first stocked lake trout in Flathead Lake in 1905 (Spencer et al. 1991). Lake trout abundance remained low until the opossum shrimp *Mysis diluviana* invaded Flathead Lake during the 1980s after being introduced in five upstream lakes (Ellis et al. 2011). The population expansion in *M. diluviana* was followed by an increase in the abundance of lake trout and nonnative lake whitefish *Coregonus clupeaformis* and extirpation of formerly abundant nonnative kokanee salmon *Oncorhynchus nerka* (Ellis et al. 2011). Native bull trout and westslope cutthroat trout *Oncorhynchus clarkii lewisi* populations also declined in the early 1990s in the upper Flathead Lake and Flathead River system due to these community changes. Concurrently, there were declines in bull trout abundance and corresponding increases in

lake trout abundance in several GNP lakes connected to Flathead Lake (Fredenberg 2002).

Many bull trout populations have experienced large declines in abundance following lake trout invasion (Fredenberg 2002; Meeuwig et al. 2008), and lake trout frequently outnumber bull trout in lakes where both species occur (Fredenberg 2002). Of the 17 bull trout populations that occur west of the Continental Divide in GNP, only five populations are considered secure from invasion, as they are found upstream of natural barriers to fish movement (Meeuwig et al. 2010). Currently, nine of the 12 (75%) unsecured lakes supporting bull trout in western GNP have been compromised by nonnative lake trout, and native bull trout populations in many of these waters are nearly extirpated (Fredenberg 2002; Meeuwig et al. 2008; Downs et al. 2011). Substantial niche overlap (e.g., competition and/or predation) is hypothesized as the mechanism driving the observed displacement (Donald and Alger 1993; Guy et al. 2011; Meeuwig et al. 2011; Ferguson et al. 2012).

Translocation of Bull Trout in Glacier National Park

The invasion of nonnative lake trout threatens the persistence of bull trout in western GNP. In response to this threat, biologists have proposed conducting within-drainage translocation to conserve imperiled populations of bull trout and establish new self-sustaining populations within GNP. Translocations of fish species have occurred in the past, but many have failed to establish populations within the site of translocation (Hendrickson and Brooks 1991; Buchannan et al. 1997). These failures are likely the

result of an inadequate understanding of the biotic and abiotic factors influencing successful establishment and persistence (Minckley 1995).

Several protocols have been developed for conducting translocations of threatened and endangered fishes (Williams et al. 1988; Minckley 1995; Dunham and Gallo 2008; Dunham et al. 2011). These protocols suggest first evaluating the recipient habitat to determine if there is sufficient quantity and quality of habitat available to support a sustainable population. This includes spawning, rearing, foraging, migrating, and overwintering habitat, which allow for the full expression of all life stages and life history strategies. These protocols also suggest identifying a suitable donor population based on life history and genetic diversity that could withstand removal of propagules without jeopardizing its own persistence (Williams et al. 1988; Minckley 1995; Dunham and Gallo 2008; Dunham et al. 2011). Additionally, these protocols recommend restricting translocation to sites where other endemic or threatened species will not be extirpated, hybridization is not likely to occur, the dispersal potential of the species has been identified and deemed acceptable, and all possible threats to the long-term persistence of the population have been identified and are considered acceptable (Williams et al. 1988; Minckley 1995; Dunham and Gallo 2008; Dunham et al. 2011).

Aquatic species introductions often change the composition of zooplankton, benthic invertebrate, amphibian, and fish communities (Hecnar and M'Closkey 1997; Marnell 1997; Carlisle and Hawkins 1998; Knapp and Matthews 2000; Knapp et al. 2001a; McDowell 2003). Furthermore, introductions of fish to historically fishless lakes have modified ecosystem structure and function (Knapp et al. 2001b; Eby et al. 2006).

Translocations of bull trout within GNP are likely to modify food-web dynamics and the structure and function of aquatic ecosystems. Biologists want to ensure that rare or threatened aquatic species do not exist in these sites to avoid extirpation of these species resulting from unpredictable ecosystem responses to bull trout translocation.

There are several uncertainties associated with translocation of bull trout in GNP. First, it is unknown if the proposed sites of translocation contain sufficient quantity and quality of habitat to support long-term population persistence. Second, it is unknown whether sensitive aquatic species exist in the proposed sites of translocation, which could be negatively impacted by introduced bull trout. Third, it is unknown if downstream populations can support removal of propagules for translocation. Therefore, the objectives of this study were to: 1) assess the potential suitability of recipient stream and lake environments for bull trout survival and persistence; 2) identify any sensitive or endemic aquatic species within the proposed sites of translocation; 3) determine if downstream populations can support translocation; and 4) use the combined information and decision-making criteria to determine overall site suitability for bull trout translocation.

Study Area

Glacier National Park encompasses approximately 4,100 km^2 in the northwestern corner of Montana, USA (Figure 1). Glacier National Park was established in 1910 and was designated the world's first International Peace Park in 1932 in conjunction with Waterton National Park, which borders GNP to the north. Glacier National Park was

designated a World Biosphere Reserve by the United Nations in 1976, and later designated a World Heritage Site in 1995.

The Lewis and Livingston mountain ranges bisect GNP, forming part of the Continental Divide in northwest Montana. Regions of the park drain into three major watersheds, including the Hudson and Missouri drainages on the east side and the Columbia drainage on the west side. Sub-basins on the west side of the park are characterized by high-gradient mountain streams interspersed with cirque and moraine lakes. Snowmelt has the greatest influence on the hydrograph in these systems. Flows peak during spring runoff (May-July) and reach base flow levels in August and September. Stream water temperatures remain cool throughout the year, and maximum August water temperatures rarely exceed 16 °C (D'Angelo 2010; Jones 2012). Montane forest is the dominant land cover at lower elevations (below 1500 m) on the west side of GNP. Douglas fir *Pseudotsuga menziesii,* lodgepole pine *Pinus contorta,* limber pine *Pinus flexilis,* white spruce *Picea glauca,* and western larch *Larix occidentalis* are the most common tree species in this zone (NPS 2013). Subalpine and alpine zones exist at higher elevations (above 1500 m), and are characterized by heavy snowfall and short growing seasons. Dwarfed Engelman spruce *Picea engelmannii* exist in low densities, and the region consists mostly of shrubs, grasses, and wildflowers (NPS 2013). Early mining and oil exploration occurred in some areas in GNP; however, mining, logging, and other forms of natural resource extraction are now prohibited. Land use is currently restricted to recreational hiking and backpacking.

Native fish species still exist in western GNP despite past introductions and invasions of nonnative species. Native fish species include bull trout, westslope cutthroat trout, mountain whitefish *Prosopium williamsoni*, pygmy whitefish *Prosopium coutleri*, longnose sucker *Catostomus catostomus*, largescale sucker *Catostomus macrocheilus*, and slimy sculpin *Cottus cognatus* (Fredenberg 2002). Other native species such as northern pike minnow *Ptychocheilus oregonensis*, peamouth *Myocheilus caurinus*, and redside shiner *Richardsonius balteatus*, are uncommon in western GNP (Fredenberg 2002; Meeuwig and Guy 2007; Downs et al. 2011). Nonnative kokanee salmon, lake trout, rainbow trout *Oncorhynchus mykiss*, brook trout *Salvelinus fontinalis*, lake whitefish *Coregonus clupeaformis* and Yellowstone cutthroat trout *Oncorhynchus clarkii bouvieri* occur sporadically throughout western GNP resulting from past stocking efforts and species invasions (Morton 1968; Marnell et al. 1987; Fredenberg 2002; Fredenberg et al. 2007; Meeuwig and Guy 2007; Meeuwig et al. 2008; Downs et al. 2011). Amphibian species native to western GNP include the long-toed salamander *Ambystoma macrodactylum*, the tailed frog *Ascaphus truei*, the boreal toad *Bufo boreas*, the Pacific tree frog *Hyla regilla*, and the Columbia spotted frog *Rana luteiventris* (Marnell 1997; Corn et al. 2005).

This study was conducted in isolated stream and lake networks in the Logging, Camas, and Lincoln creek drainages of western GNP, Montana (hereafter referred to as sites) (Figures 2-4). Logging and Camas creeks are tributaries to the North Fork Flathead River, and Lincoln Creek is a tributary to the Middle Fork Flathead River.

METHODS

The Camas, Lincoln, and Logging sites were selected by managers as potential bull trout translocation areas because: (1) native bull trout populations exist downstream of these sites, providing the possibility of within-drainage translocation; (2) the sites are isolated above natural barriers (e.g., waterfalls) to fish migration, preventing future species invasions; and (3) existing salmonid populations provide evidence that these sites may provide physical and biological conditions suitable for bull trout persistence.

Existing protocols for fish species introductions (Williams et al. 1988; IUCN 1998; Dunham et al. 2011) were reviewed to develop a general framework for assessing the feasibility of bull trout translocation (Figure 5). Within this framework, three major components influencing translocation success were identified: recipient habitat, recipient community, and donor population. Specific questions were created to evaluate the suitability of each major component using criteria representing characteristics of highly suitable bull trout sites within the Columbia River drainage (CRD). Thresholds for criteria were subjectively created using data investigating the relationship between bull trout density and physical and biological characteristics of bull trout inhabited sites within the CRD (Appendix L). Specifically, thresholds indicating high suitability relate to characteristics observed in sites with high bull trout density. Thresholds indicating moderate suitability relate to characteristics observed in sites with low bull trout density. Thresholds indicating low suitability relate to characteristics of sites where bull trout were rarely observed.

A scoring system was developed to rank the relative suitability of each site (Tables 1-3). Each site was assigned a score for each criterion based on data collected. A score of 1 indicates characteristics of the site are highly suitable for bull trout persistence. A score of 0.5 indicates characteristics are moderately suitable for bull trout persistence, suggesting bull trout are found in systems exhibiting such characteristics, but are less common or exist at lower densities. A score of 0.5 was included only for those criteria where data regarding moderately suitable conditions were available. If characteristics measured did not meet the specified criterion, they received a score of -1, indicating characteristics of the proposed site are less suitable for bull trout persistence. A score of 0 indicates there is no information available and further research is needed.

For each site, scores assigned to criteria within each major component were averaged. The average score for the recipient habitat component was included twice in calculating the overall score of each site to illustrate the importance of quality habitat for bull trout survival. The four scores were averaged, resulting in an overall score for each site. A scale was created to rank sites based on their overall suitability scores. This scale was created by randomly assigning scores for each criterion and calculating the resulting overall score. This process was repeated 10,000 times, and, on average, sites receiving overall scores of 0.7 and above contained characteristics representative of highly suitable bull trout sites. Likewise, sites receiving scores between 0.4 and 0.69 contained characteristics representative of moderately suitable sites. Therefore, sites with an overall score of 0.7 – 1.0 were considered highly suitable, sites with an overall score of

0.4 – 0.69 were considered moderately suitable, and sites with an overall score below 0.4 were considered to have low suitability for bull trout translocation.

Recipient Habitat

Stream Assessment

Spatially explicit habitat surveys were conducted within each site to determine the quantity and quality of stream habitat present in each site. Habitat surveys were conducted using a modified Hankin and Reeves (1988) habitat assessment. Habitat surveys occurred in August 2010 and 2011 during summer base flows to reflect restrictions in stream habitat availability. Individual mesohabitat units were classified as pool, glide, riffle, or cascade (Bisson et al. 1982).

Individual mesohabitat units were assessed to determine habitat characteristics. Pool density, percent instream cover, and substrate composition were measured. The length and width (to the nearest 0.1 m) of each mesohabitat unit was measured to estimate total stream area. Maximum pool depth was measured to the nearest 0.1 m. Substrate composition was visually estimated as the proportion of the stream bottom comprised of each substrate size class (Moore et al. 2002) using a modified Wentworth scale as follows: sand/silt (< 0.2 cm), gravel (0.2 - 7.5 cm), cobble (> 7.5, < 30.0 cm), boulder (≥ 30.0 cm), and bedrock (Wentworth 1922; Cummins 1962). Instream cover was visually estimated as the proportion of the mesohabitat unit area comprised of each cover type. Cover types included large woody debris (LWD), undercut bank (UCB), boulder (BLD), overhanging vegetation (OHV), and backwater (BKW) (Kaufmann et al.

1999; Tennant 2010). Large woody debris was classified as any piece of wood greater than 3 m in length and greater than 10 cm in diameter within the wetted width, or logjams consisting of many pieces of wood of varied sizes (Rich et al. 2003). Undercut bank was classified as the proportion of both stream banks within each mesohabitat unit undercut more than 0.2 m. Overhanging vegetation included vegetation hanging within 1 m of the stream surface (Kaufmann et al. 1999). Boulder cover was categorized as the proportion of the streambed comprised of rocks ≥ 30.0 cm in diameter (Kaufmann et al. 1999).

Stream water temperatures were also measured in each site. Water temperature was measured hourly from August 2011 through September 2012 using Hobo® Pro v2 water temperature data loggers (Onset Computer Corporation, Bourne, Massachusetts). Data loggers were installed upstream and downstream of lakes in each site, except above Lake Ellen Wilson and Lake Evangeline, where permanent inlet streams were absent.

Lake Assessment

To determine the quantity of lacustrine habitat available in each site, physical characteristics of each lake were measured. The surface area of each lake was determined using the Montana Fish, Wildlife & Parks' MFISH database (available at http://fwp.mt.gov/fishing/mFish/). Maximum depth was measured using a Vexilar® LPS-1 handheld depth finder (Vexilar, Inc., Minneapolis, Minnesota).

In addition to physical characteristics, water temperature was measured in each lake to determine thermal suitability for bull trout. Water temperature was measured using Hobo® Pro v2 data loggers. Data loggers were fastened to an anchor line at five-meter intervals beginning approximately 0.5 m below the surface. The line was anchored

at a depth of 30 m as previous research suggests the thermocline typically occurs shallower than 30 m (Gorham and Boyce 1989). In Grace and Camas lakes, the line was anchored at the lakes deepest point, because both lakes are shallower than 30 m. Water temperature was recorded every hour from August 2011 through September 2012.

Recipient Community

Stream Assessment

Community composition sampling was conducted in each site to estimate the presence of competing, hybridizing, or sensitive native aquatic species. Distinct reaches were designated within each stream based on changes in channel geomorphology, gradient, or by divisions from falls, lakes, or stream junctions (Figures 2-4). Stream reaches were designated to account for differences in species distributions, as community composition can change depending on physical characteristics such as elevation, gradient, or stream order (Rahel and Hubert 1991; Rieman and McIntyre 1995; Rich et al. 2003).

The presence of fish and amphibian species in each study reach was estimated using single-pass electrofishing surveys (Rieman and McIntyre 1995; Lazorchak et al. 1998; Rich et al. 2003). Electrofishing surveys were conducted in each reach using an LR-24 backpack electrofisher (Smith-Root, Inc., Vancouver, Washington) during base flows in August 2010 and August 2011. Individual pool and glide mesohabitat units were grouped as slow water units, whereas riffles and cascades were grouped as fast water units to facilitate sampling and remain consistent with previous studies (Arend 1999; Tennant 2010). Every fifth fast and every fifth slow water mesohabitat unit was

sampled, beginning with the furthest downstream unit and proceeding upstream. Approximately 12 % of total stream length (373.3 m) was sampled in Camas Creek, 17 % (51.5 m) in Lincoln Creek, and 20% (619.4 m) in Logging Creek (Appendix C). All fish and amphibians captured were identified to species, fish lengths were recorded to the nearest mm, and all specimens were released.

Kick netting was used in each stream reach to sample invertebrate species. Sampling was conducted in one slow and one fast water mesohabitat unit within each reach, as invertebrate species composition can vary between slow and fast water mesohabitat types (Logan and Brooker 1983). Mesohabitat units containing the dominant substrate size class present within the reach were non-randomly selected for sampling. The kick net used was a D-frame style with 500 µm mesh (Wildlife Supply Company, Yulee, Florida) and methods for netting followed Davis et al. (2001). Invertebrate samples were preserved in 70% ethanol.

Invertebrate samples were pooled among stream reaches within a site. Samples were processed using a fixed fraction method of subsampling, where one fourth of the total sample specimens were removed and identified to family (Barbour and Gerritsen 1996). This method allows efficient processing of invertebrate samples while maximizing the likelihood of identifying all families present in the sample (Barbour and Gerritsen 1996). Families identified were checked against the Montana Species of Concern list (available at www.mtnhp.org). Specimens in families listed were identified to species to determine if they warranted designation as a sensitive aquatic species.

Lake Assessment

To estimate fish species present, gill netting occurred during the summer of 2010 in Grace Lake and during the summer of 2011 in Camas Lake, Lake Ellen Wilson, and Lake Evangeline. Gill nets were sinking monofilament nets that measured 2-m deep by 38-m long and had five panels of equal length containing 19-, 25-, 32-, 38-, and 51-mm bar mesh (Meeuwig and Guy 2007; Meeuwig et al. 2008). Nets were set perpendicular to the shoreline, alternating between the large and small mesh near shore. Four nets were set systematically at the eastern, western, northern, and southernmost points along each shoreline. Nets soaked for approximately one hour, except for one set that soaked overnight. Sampling time totaled 14.5 hours in Lake Ellen Wilson, 16 hours in Camas Lake, 16.5 hours in Grace Lake, and 19.3 hours in Lake Evangeline (Appendix E). Additional net sets did not occur to prevent unnecessary bycatch. Captured fish were identified to species, measured to the nearest mm, and released.

Littoral zones were sampled to characterize the shallow-water fish assemblage using a LR-24 backpack electrofisher (Smith-Root, Inc., Vancouver, Washington). Sample sites were systematically selected at the most eastern, western, northern, and southernmost point of each shoreline, where shoreline topography would permit wading. Sites were approximately 50-m long, with the exception of Grace Lake, where five sites (55-, 60-, 65-, 70-, and 85-m long) were sampled. Fish captured were identified to species, measured to the nearest mm, and released.

Kick net samples were conducted in each lake to sample the aquatic invertebrate assemblage. Four samples were systematically collected from the eastern, western,

southern, and northernmost points along each shoreline. The kick net used was a D-frame style with 500 µm mesh (Wildlife Supply Company, Yulee, Florida) using methods modified for lake environments from Davis et al. (2001). Samples were processed using the method described previously.

Vertical net tows were conducted in each lake to sample the zooplankton assemblage. Zooplankton were sampled using a Wisconsin-style sampling net 130 mm in diameter with 63 µm Nitex® mesh (Wildlife Supply Company, Yulee, Florida). Six tow sites were sampled in each lake following a stratified random design; three tows were conducted from approximately 30 m or the maximum depth, and three from areas < 10 m deep, except in Camas Lake, where all samples were from depths ≤ 9 m because maximum depth was 9 m. Samples were processed using the method described previously.

Amphibian presence was evaluated via visual encounter surveys (Crump and Scott 1994; Corn et al. 2005). Emergent vegetation along lake shorelines was sampled for tadpole and egg presence using a sweep net. The sweep net used was 40.6 cm square and consisted of 3 mm nylon mesh. Surveys were conducted in each site between June and August 2011, when juvenile amphibians were expected to be present (Pilliod et al. 2010). Adult and juvenile amphibians observed during visual encounter surveys were identified to species, while egg masses were collected and identified in the laboratory.

Donor Populations

Previous research was reviewed to estimate the likelihood that potential donor populations could support a successful translocation. Specifically, relative abundance (represented as fish/net hour) and genetic heterozygosity (Meeuwig and Guy 2007; Meeuwig et al. 2007) were examined to determine the state of bull trout populations downstream of each site. Self-sustaining bull trout populations in GNP exhibit relative abundances of approximately 0.2 fish/net hour (Meeuwig and Guy 2007; Meeuwig et al. 2007). Therefore, donor populations with relative abundances greater than or equal to 0.2 fish/net hour were considered highly suitable for translocation.

Higher levels of genetic heterozygosity are associated with higher levels of fitness and evolutionary potential (Allendorf and Leary 1986). Observed heterozygosity has been estimated for other bull trout populations in the CRD. Specifically, genetic heterozygosity was observed between 0.602 and 0.792 for bull trout populations in the main stem of the Bitterroot River, Montana, between 0.747 and 0.763 for populations in the West Fork Bitterroot River, Montana, and between 0.640 and 0.756 for populations in the East Fork Bitteroot River, Montana (Nyce et al. 2013). Mean heterozygosity of 0.53, 0.59, and 0.69 was calculated for bull trout populations in Warm Springs Creek, Montana, the Metolius River, Oregon, and the Swan River, Montana, respectively (DeHaan et al. 2008; DeHaan et al. 2010; DeHaan et al. 2011). Furthermore, observed heterozygosity varied from 0.335 to 0.696 for bull trout populations in GNP not isolated by dispersal barriers (Meeuwig and Guy 2007). A threshold for population heterozygosity was subjectively created based on these estimates. As a majority of these

populations exhibit heterozygosity greater than 0.5, potential donor populations with heterozygosity levels greater than 0.5 were considered suitable for translocation.

RESULTS

Recipient Habitat

Stream Assessment

All three sites were rated highly suitable for bull trout based on the quality of physical stream habitat available (Table 4; Figure 6). The Logging site contained mainly riffle habitat, gravel substrate, and large woody debris cover (Table 5). The Camas site was predominately glide habitat, gravel substrate, and overhanging vegetation cover (Table 5). The Lincoln site was comprised mostly of riffle habitat, cobble substrate, and large woody debris cover (Table 5).

Although each site contained high-quality habitat overall, specific microhabitat types within individual habitat units varied among sites. The Camas site contained a higher proportion of small gravel per habitat unit than the Logging site, while the Logging site contained a higher proportion of large gravel per habitat unit than the Lincoln or Camas sites (Table 6). Additionally, the Camas and Logging sites contained a higher proportion of boulder, backwater, undercut bank, and overhanging vegetation cover per habitat unit than the Lincoln site (Table 6).

The Camas and Logging sites were rated as highly suitable based on the quantity of stream habitat available (Table 4; Figure 6). The quantity of stream habitat available in the Camas and Logging sites were comparable to neighboring systems supporting bull trout. Conversely, the Lincoln site was rated as less suitable based on the quantity of stream habitat available, containing less than 300 m of stream habitat (Table 7; Figure 6).

In addition to mainstem and side-channel habitat, the Camas and Lincoln sites contained off-channel lentic mesohabitat units. Although these habitats were not considered part of the stream channel and therefore were not included in calculations of total stream length or proportions of physical habitat characteristics, they still provide important habitat for amphibians and other aquatic species. Therefore, characteristics of these mesohabitat units were recorded (Appendix K).

Stream temperatures were similar among sites, and all sites received scores reflecting moderately suitable habitat based on mean August stream temperature (Table 4; Figure 6). Mean August stream temperature varied between 13° and 15°C, except in Reach 2 of Camas Creek, where mean August stream temperature was 15.8°C (Table 8; Appendix A.1), and Reach 5 of Logging Creek, where mean August stream temperature was 10.8°C (Table 8; Appendix A.5). Nonetheless, both the Camas and Logging sites received a score of moderately suitable as mean August stream temperatures were observed between 13° and 15°C in Reach 3 of Camas Creek and Reach 1 of Logging Creek (Table 8; Appendix A.2 and A.4). All sites received a score of highly suitable for maximum daily stream temperature during September and October (Table 4; Figure 6), because maximum daily stream temperatures were below the 9°C threshold suggested to initiate spawning by 10 October, except in Reach 1 of Logging Creek, where stream temperatures were below this threshold by 16 October (Appendix A.4).

Lake Assessment

The Camas and Lincoln sites received scores of highly suitable regarding the quantity of lacustrine habitat available (Table 4; Figure 6). Conversely, the Logging site

received moderately suitable scores due to its shallow (< 16 m) maximum depth (Tables 4 and 9; Figure 6). The Lincoln site contained the most lacustrine habitat, while the Logging site had the least lacustrine habitat available (Table 9).

All sites received highly suitable scores for lake temperature, as thermally suitable water temperatures were observed in all sites (Table 4; Figure 6). Mean August temperatures below 14°C were first observed in the Lincoln site (Lake Ellen Wilson) at a depth of 5 m, in the Camas site (Lake Evangeline) at a depth of 10 m, and in the Logging site (Grace Lake) at a depth of 7 m (Table 10; Appendix B). Additionally, maximum August temperatures were recorded at or below 16°C in the Lincoln site at a depth of 5 m, in the Camas site at a depth of 10 m, and in the Logging site at a depth of 2 m (Table 10; Appendix B).

Recipient Community

The Lincoln site was rated as highly suitable based on the potential impacts to sensitive species because no threatened, endangered, or sensitive native aquatic biota were detected (Tables 11 and 12; Figure 6). Conversely, both the Camas and Logging sites received a least suitable rating for this metric due to the presence of boreal toads, which are listed as a species of special concern in Montana (Tables 11 and 12; Figure 6). Boreal toad tadpoles were observed in the Camas site in Camas Creek in August 2012, while a single adult toad was encountered in the Logging site along the shoreline of Grace Lake in August 2010. No additional sensitive, threatened, or endangered species were observed at any site (Table 12).

The Camas and Logging sites were rated highly suitable based on compatibility with the existing biotic community because no competing or hybridizing species were detected (Tables 11 and 12; Figure 6). Additionally, Yellowstone cutthroat trout was the only fish species detected in either site. The Lincoln site, however, was rated least suitable because nonnative brook trout were sampled (Tables 11 and 12; Figure 6). No additional competing or hybridizing species were detected at any site (Table 12).

Donor Populations

The Lincoln and Logging sites were rated highly suitable for translocation based on the observed genetic heterozygosity of bull trout populations downstream of each site (Table 13; Figure 6). Previous analyses estimated genetic heterozygosity of bull trout populations downstream of the Lincoln and Logging sites at 0.5302 and 0.6667, respectively (Table 14; Meeuwig and Guy 2007). The Camas site, however, was rated as having low suitability for translocation as observed genetic heterozygosity in downstream Trout and Arrow lakes was estimated at 0.2059 and 0.2063, respectively (Table 14; Meeuwig and Guy 2007). Observed values for bull trout populations in Trout and Arrow lakes are similar to other isolated bull trout populations in GNP (Meeuwig and Guy 2007).

The Lincoln and Logging sites were rated as having low suitability for bull trout translocation based on the relative abundance of bull trout observed for populations downstream of each site (Table 13, Figure 6). Past gill netting surveys estimated relative abundance of bull trout to be 0.069 fish/net hour downstream of the Lincoln site and

0.057 fish/net hour downstream of the Logging site (Table 14; Meeuwig and Guy 2007). These estimates are consistent with estimates for bull trout populations in GNP that have experienced declines from nonnative lake trout invasion (Meeuwig and Guy 2007). Conversely, relative abundances in Trout and Arrow lakes downstream of the Camas site were estimated to be approximately 0.440 fish/net hour and 0.230 fish/net hour, respectively (Table 14; Meeuwig and Guy 2007). These estimates suggest bull trout abundance in Trout and Arrow lakes is sufficiently high to support removal of propagules for translocation.

Scoring Summary

The Camas site is moderately suitable for bull trout translocation, having an overall feasibility score of 0.475 (Table 15). The site contains highly suitable quantity and quality of habitat, a compatible biotic community, and the population of bull trout in downstream Trout and Arrow lakes would likely withstand removal of propagules for translocation. However, bull trout in downstream Trout and Arrow lakes exhibit low genetic diversity relative to other bull trout populations in GNP. The Logging site is also moderately suitable for translocation, having an overall feasibility score of 0.450 (Table 15). The Logging site provides highly suitable quantity and quality of habitat, a compatible biotic community, and the bull trout population in downstream Logging Lake has relatively high heterozygosity. However, relative abundance of bull trout in downstream Logging Lake is low, suggesting the Logging Lake population may not withstand removal of propagules for translocation. The Lincoln site has low suitability

for bull trout translocation and has an overall feasibility score of 0.375 (Table 15). The Lincoln site contains high quality habitat, but the quantity of stream habitat is extremely limited. Additionally, the biotic community is not compatible with bull trout, as nonnative brook trout were detected. Furthermore, the relative abundance of bull trout in downstream Lincoln Lake is low, suggesting removal of bull trout for translocation may jeopardize the Lincoln Lake population.

DISCUSSION

Translocations are becoming more prevalent as a tool in native species conservation (Griffith et al. 1989). However, translocations to recover native fishes have resulted in mixed success, primarily owing to inadequate assessments of their feasibility prior to implementation. Here, a framework was developed to assess the feasibility of translocating a threatened char species into isolated stream and lake habitats in GNP, Montana, based on three major components: the recipient habitat; the recipient community; and the donor population. The final translocation assessment was based on a scoring system that included quantitative measures of feasibility developed from systems within the CRD currently supporting bull trout. Results indicate that the relative feasibility for translocating bull trout is moderate for the Camas and Logging sites, and low for the Lincoln site. This information will assist biologists in making informed decisions regarding bull trout translocation in GNP and will provide a framework for implementing this type of translocation assessment elsewhere.

There is a growing debate concerning the appropriateness of conducting translocations for species conservation. Some researchers question the ethics of conducting translocation based on unintended negative consequences that have resulted from past translocation attempts, including the eradication of native species and the establishment of invasive species (Mueller and Hellmann 2008; Ricciardi and Simberloff 2009; Minteer and Collins 2010). Furthermore, it has been suggested feasibility assessments cannot predict the ecosystem effects resulting from unforeseen trophic cascades following species translocation (Ricciardi and Simberloff 2009). Conversely,

other researchers suggest translocation can be a valuable tool for the conservation of threatened or imperiled species if conducted appropriately (Hunter 2007; McLachlan et al. 2007; Olden et al. 2011; Loss et al. 2011; Thomas 2011; Perez et al. 2012). Given the results of this study, translocation should be considered an appropriate conservation tool for bull trout in GNP. The isolation of the proposed sites combined with the restricted dispersal potential following translocation eliminates the possibility of bull trout invasion outside the translocation sites. Furthermore, no endemic aquatic species were detected that could be impacted from unforeseen trophic interactions. Finally, translocation provides a feasible alternative for conserving local bull trout populations facing imminent extirpation from nonnative species invasion.

Specific guidelines have been created to help implement successful species translocations (IUCN 1998; IUCN 2013). For fishes, detailed guidelines have been developed focusing on the reintroduction or translocation of imperiled or endangered species (Williams et al. 1988). These guidelines address general considerations before, during, and following fish species reintroductions and translocations. More recently, a framework was developed to address the feasibility of reintroducing bull trout to the Clackamas River, Oregon, using specific criteria to identify suitable habitat and donor populations (Dunham and Gallo 2008; Dunham et al. 2011). Furthermore, the framework presented by Dunham et al. (2011) outlines a scoring procedure used to calculate an overall suitability score based on several important persistence criteria. Here, I expand on the framework constructed by Dunham et al. (2011) by presenting specific criteria used to evaluate site suitability for bull trout translocation. Additionally, distinct

thresholds for distinguishing between highly suitable, moderately suitable, and least suitable sites were developed using data from systems currently supporting bull trout populations within the CRD.

Stream temperatures were monitored at a single point location in each stream reach for the duration of the project, which were assumed to be representative of the entire reach. However, stream temperatures are influenced by many factors, including incoming solar radiation, riparian shading, hyporheic exchange, and substrate type (Constantz 1998; Baxter and Hauer 2000; Johnson 2004). As such, water temperatures recorded at single point locations differ from water temperatures throughout the stream. Therefore, scores regarding the suitability of stream temperatures could change depending on the location of water temperature monitors.

The timing and duration of sampling was a potential source of bias in describing site community structure, as the number of species detected during sampling is directly related to sampling effort (Angermeier and Smogor 1995). Fish and amphibian species detected are assumed to be representative of aquatic vertebrate species present in these sites given the duration of sampling and the similarities of sampling methodologies to other studies conducted to estimate fish and amphibian presence in GNP (Corn et al. 2005; Meeuwig et al. 2008). In contrast, invertebrate species composition has been shown to change seasonally (Hawkins and Sedell 1981; De Stasio Jr. 1990), and it is possible additional species exist in the sites that were not detected during sampling. More thorough invertebrate sampling is necessary to construct a more complete list of invertebrate species present in these sites. However, records of threatened or endangered

aquatic invertebrates and their distributions were consulted following sampling (Montana Natural Heritage Program 2013). Distributions of known threatened or endangered invertebrates do not overlap with the Camas, Lincoln, or Logging sites, providing additional evidence that sensitive invertebrate species do not exist at the sites (Montana Natural Heritage Program 2013).

Stream temperatures observed in each site were representative of moderately suitable bull trout habitat. However, these sites will likely provide adequate thermal habitat, as bull trout distribution is generally limited by water temperatures exceeding 15° C (Rieman and McIntyre 1993; Jones et al. 2013). Additionally, bull trout have been observed in water temperatures exceeding 16°C in other systems (Saffel and Scarnecchia 1995; Dunham and Chandler 2001; Dunham et al. 2003). Water temperatures representative of highly suitable bull trout habitat were documented in lakes within each site. These cooler water temperatures can likely be used by bull trout as refugia during periods of warm stream temperatures (Swanberg 1997).

The Logging site was rated moderately suitable based on lacustrine habitat available. The maximum depth of Grace Lake falls below the threshold representing maximum depth of the majority (75%) of lakes within the CRD supporting bull trout. However, there are multiple lakes within the CRD, including two lakes within GNP (Akokala Lake and Rogers Lake) supporting bull trout with maximum depths less than 15 m (Meeuwig and Guy 2007). Additionally, water temperatures recorded at all depths in Grace Lake are suitable for bull trout survival. This provides evidence suggesting lacustrine habitat in the Logging site is suitable for bull trout.

Yellowstone cutthroat trout was the only fish species detected in the Camas and Logging sites. If translocation occurs in either site, Yellowstone cutthroat trout will likely provide a food source for bull trout. Predation on Yellowstone cutthroat trout is considered acceptable because Yellowstone cutthroat trout are nonnative to these sites. Although the native distribution of bull trout and Yellowstone cutthroat trout do not overlap, these species have been observed in sympatry in other systems in GNP, namely Trout and Arrow lakes in the Camas drainage downstream of the Camas site. Bull trout have persisted in sympatry with Yellowstone cutthroat trout in these lakes since Yellowstone cutthroat trout were stocked prior to the 1950s (Morton 1968; Marnell et al. 1987). Conversely, nonnative brook trout was the only fish species found in the Lincoln site. Brook trout may hybridize with bull trout where the two species occur in sympatry (Leary et al. 1983; Kanda et al. 2002). Brook trout also displace bull trout through competition and exhibit a competitive advantage over bull trout in natural and laboratory experiments (Gunckel et al. 2002; McMahon et al. 2007). Consequently, translocation of bull trout into the Lincoln site would have to be preceded by the eradication of brook trout using piscicides or alternate removal methods (e.g., netting, redd excavation). The elimination of brook trout would make the Lincoln site more suitable for bull trout translocation.

The detection of boreal toads in the Camas and Logging sites resulted in each site receiving unfavorable scores regarding potential impacts to sensitive species. Boreal toads are widespread throughout their range, but are classified as an S2 species of special concern in Montana due to potentially declining habitat and abundance (Montana Natural

Heritage Program 2013). Fish introductions have been shown to negatively affect amphibian species (Hecnar and M'Closkey 1997; Knapp and Matthews 2000; Pilliod et al. 2010). For example, amphibian species richness and density has been shown to decline in systems after predatory fish introductions (Hecnar and M'Closkey 1997; Pilliod et al. 2010). It is possible the introduction of bull trout to these sites could negatively influence local boreal toad populations. However, it is unlikely these sites support a significant proportion of the total population of this species within GNP. Boreal toads are the most widespread amphibian in GNP, and have been detected in lowland valleys to alpine areas at or even slightly above the tree line in the Flathead River, Missouri River, and Saskatchewan River drainages in GNP (Marnell 1997). Additionally, only adult boreal toads were observed near Grace Lake. Searches for tadpoles of this species were unsuccessful, and it is possible Grace Lake is not used as a site of reproduction. Adults may have been encountered due to the wandering nature of the species, which have been observed traveling more than two kilometers from sites of reproduction (Muths 2003). It is likely translocation into these sites would not have substantial effects on the boreal toad population within GNP.

Past protocols for fish translocations suggest evaluating the potential for dispersal of individuals after establishment to prevent introduction of the species to undesired locations (Williams et al. 1988; Minckley 1995). Inlets in both the Camas and Lincoln sites are meltwater streams, which are uninhabitable due to their ephemeral nature and high gradients. The Logging site is contained at its upstream boundary by a second fish passage barrier, preventing movement of bull trout further upstream. Dispersal potential

within each translocation site is limited to downstream drift over natural barriers. Although undesirable, downstream movement of bull trout is inconsequential to bull trout distribution within the park as populations of bull trout currently exist downstream of each site.

Existing protocols also suggest selecting sites where future threats have been minimized (Williams et al. 1988; Minckley 1995; Dunham and Gallo 2008; Dunham et al. 2011). Future disturbances to the proposed sites are minimal, as anthropogenic activities known to cause aquatic habitat degradation such as logging, mining, road construction, and urbanization will not affect any of these drainages. However, demographic and environmental stochasticity pose serious threats for isolated headwater populations and could potentially affect bull trout in these sites if translocation occurs (Hilderbrand and Kershner 2000).

Isolating fish populations above barriers has been shown to be detrimental to long-term persistence, as loss of connectivity between populations reduces gene flow (Allendorf 1983). Reductions in genetic diversity reduce the likelihood a population will persist by increasing the risk of genetic inbreeding. Conversely, isolation may be the only conservation alternative when populations are threatened by nonnative species invasion (Novinger and Rahel 2003). Eight kilometers of stream has been determined to be necessary to support isolated cutthroat trout populations (Hilderbrand and Kershner 2000), and similar approaches have been used in GNP (Muhlfeld et al. 2012). None of the sites evaluated in this study contain the amount of stream habitat suggested to be necessary to prevent the eventual loss of a population through genetic inbreeding or

environmental and demographic stochasticity (Hilderbrand and Kershner 2000). However, the presence of lacustrine habitat within each site likely negates the absence of the suggested quantity of stream habitat, given the lacustrine habitat will provide suitable rearing, foraging, and overwintering opportunities if translocation occurs. Additionally, it should be noted that isolation of bull trout in GNP may be beneficial despite the risk, as establishment of nonnative brook trout and lake trout have been associated with declines in bull trout abundance within GNP (Fredenberg 2002; Meeuwig et al. 2008). Isolation may be a way to protect bull trout populations from extirpation until a more permanent solution to their decline is found.

Increases in air temperatures associated with climate warming have been observed within the Rocky Mountain region of North America at two to three times the global rate (Pederson et al. 2010). These increases are associated with higher frequencies of winter flood events, increased stream temperatures, and higher incidence of wildfire (Isaak et al. 2010; Isaak et al. 2012; Wenger et al. 2011). Stream temperatures within the proposed sites are approaching thermal limits for suitable habitat and may exceed optimal thermal ranges for bull trout in the future (Isaak et al. 2010; Jones et al. 2013). Furthermore, observed increases in winter flood frequency within the Flathead River drainage could impact translocated bull trout populations (Hamlet and Lettenmaier 2007; Isaak et al. 2012). Additionally, glacial recessions and reductions in seasonal snowpack in GNP may result in low base flows during summer months and periods of spawning and incubation (Hall and Fagre 2003; Isaak et al. 2012). However, selected sites could serve as “refugia”

from existing threats given they currently contain suitable quantity and quality of habitat and will prevent future invasion of nonnative species.

Uncertainties exist concerning this framework and the translocation of bull trout in GNP. First, this study evaluated the suitability of proposed sites based on data collected over a two-year period. Characteristics measured represent a snapshot in time and are likely to change, as they are dependent on many environmental factors that cannot be predicted. It is possible sites determined to be suitable based on this framework could become unsuitable in the future due to some unpredictable natural occurrence, such as wildfire. Second, translocation of a top-level predator will likely influence trophic structure and function. Although sampling was conducted to estimate community composition, it is impossible to predict all trophic interactions that will be affected by translocation. It is possible bull trout translocation into these sites could have unforeseen impacts on the aquatic and terrestrial community composition.

This framework was developed to address important criteria for bull trout survival and persistence based on existing literature and site-specific biological and physical habitat data. Translocation success could also be related to discharge, hyporheic exchange, substrate embeddedness, disease transmission, and rates of primary productivity, however, these factors were not measured in this study given logistical and budgetary constraints. Thresholds evaluating site suitability based on these factors could be easily integrated into this framework. Additionally, thresholds for this framework were derived from multiple studies reporting bull trout abundance in relation to specific

habitat characteristics. Subjectivity in creating these thresholds could be minimized if specific habitat suitability indices for bull trout were developed.

Although this study focuses on bull trout translocation in GNP, this framework can be used to assess the feasibility of translocating other fish species. Biologists are encouraged to build upon or modify criteria presented here to reflect the biological requirements specific to the target species. Additionally, weighting of scores can be adjusted to reflect the importance of specific criteria crucial to conducting successful translocation. This framework is a guideline and should be interpreted based on the unique situation to which it is applied. In some cases, translocation into moderately suitable sites may be warranted given the direness of the situation or the lack of feasible conservation alternatives. Finally, scores for individual criteria should not be overlooked, as the score for one individual question may prove to be more important than the overall score.

Once translocation occurs, it is imperative that research and monitoring be conducted to evaluate translocation success. Monitoring should focus on estimating survival, reproductive effort and success, and juvenile recruitment, and should resemble the plan established following bull trout reintroduction to the Clackamas River, Oregon (USFWS et al. 2011), while incorporating additional techniques to estimate bull trout abundance and habitat use in lacustrine environments. Monitoring and evaluation is a critical step to assess translocation success and will provide insight into the usefulness of this framework in identifying suitable translocation sites.

Table 1.- Criteria used to evaluate the suitability of the recipient habitat in each site.

Major Component	Question	Criteria	Score	Camas	Lincoln	Logging
Recipient Habitat	Is habitat quality suitable for bull trout?	Percent stream comprised of pool habitat units >4%	1			
		No information	0			
		Percent stream comprised of pool habitat units <4%	-1			
		Coarse substrate (> 75 mm) present	1			
		No information	0			
		Coarse substrate (> 75 mm) absent	-1			
		Gravel substrate (20 – 75 mm) present	1			
		No information	0			
		Gravel substrate (20 – 75 mm) absent	-1			
		Proportion cover in stream habitat ≥15%	1			
		No information	0			
		Proportion cover in stream habitat <15%	-1			
		Mean August stream temperature ≤13°C	1			
		Mean August stream temperature 13.1-15°C	0.5			
		No information	0			
		Mean August stream temperature >15°C	-1			

(Table 1.- continued)

Major Component	Question	Criteria	Score	Camas	Lincoln	Logging
Recipient Habitat	Is habitat quality suitable for bull trout?	Maximum daily stream temperature ≤ 9°C during September/October	1			
		No information	0			
		Maximum daily stream temperature >9°C during September/October	-1			
		Mean August lake temperature ≤14°C; maximum lake temperature ≤16°C	1			
		Mean August lake temperature 14.1-15°C; maximum lake temperature ≤16°C	0.5			
		No information	0			
		Mean August lake temperature >15°C; maximum lake temperature >16°C	-1			
Recipient Habitat	Is habitat quantity suitable for bull trout?	Stream length greater than or equal to neighboring systems supporting bull trout	1			
		No information	0			
		Stream length less than neighboring systems supporting bull trout	-1			
		Maximum lake depth > 16 m	1			
		Maximum lake depth 2.2-16 m	0.5			
		No information	0			
		Maximum lake depth < 2.2 m	-1			
		Lake surface area > 25 ha	1			
		Lake surface area 3.4 – 25 ha	0.5			
		No information	0			
		Lake surface area < 3.4 ha	-1			

Table 2.- Criteria used to evaluate the suitability of the recipient community in each site.

Major Component	Question	Criteria	Score	Camas	Lincoln	Logging
Recipient Community	Compatibility with existing aquatic community?	Hybridizing or competing species not detected	1			
		No information	0			
		Hybridizing or competing species detected	-1			
	Adverse impacts to other sensitive aquatic species?	Threatened, endangered, or sensitive native aquatic species not detected	1			
		No information	0			
		Threatened, endangered, or sensitive native aquatic species detected	-1			

Table 3.- Criteria used to evaluate the suitability of the donor population downstream of each site.

Major Component	Question	Criteria	Score	Camas	Lincoln	Logging
Donor Population	Does donor population contain sufficient adaptive potential?	Observed genetic heterozygosity ≥ 0.5	1			
		No information	0			
		Observed genetic heterozygosity < 0.5	-1			
	Is donor population robust to removal of propagules?	*C/f* estimates ≥ 0.2 fish/net hour	1			
		No information	0			
		C/f estimates < 0.2 fish/net hour	-1			

Table 4.- Scores for criteria used to evaluate the suitability of the recipient habitat of each site. A score of 1 represents highly suitable habitat, a score of 0.5 represents moderately suitable habitat, and a score of -1 represents habitat of low suitability. A score of 0 indicates the information is unknown and additional research is needed.

Major Component	Question	Criteria	Score	Camas	Lincoln	Logging
Recipient Habitat	Is habitat quality suitable for bull trout?	Percent stream comprised of pool habitat units >4%	1	X	X	X
		No information	0			
		Percent stream comprised of pool habitat units <4%	-1			
		Coarse substrate (> 75 mm) present	1	X	X	X
		No information	0			
		Coarse substrate (> 75 mm) absent	-1			
		Gravel substrate (20 – 75 mm) present	1	X	X	X
		No information	0			
		Gravel substrate (20 – 75 mm) absent	-1			
		Proportion cover in stream habitat ≥15%	1	X	X	X
		No information	0			
		Proportion cover in stream habitat <15%	-1			
		Mean August stream temperature ≤13°C	1			
		Mean August stream temperature 13.1-15°C	0.5	X	X	X
		No information	0			
		Mean August stream temperature >15°C	-1			

(Table 4 continued)

Major Component	Question	Criteria	Score	Camas	Lincoln	Logging
Recipient Habitat	Is habitat quality suitable for bull trout?	Maximum daily stream temperature ≤ 9°C during September/October	1	X	X	X
		No information	0			
		Maximum daily stream temperature >9°C during September/October	-1			
		Mean August lake temperature ≤14°C; maximum lake temperature ≤16°C	1	X	X	X
		Mean August lake temperature 14.1-15°C; maximum lake temperature ≤16°C	0.5			
		No information	0			
		Mean August lake temperature >15°C; maximum lake temperature >16°C	-1			
Recipient Habitat	Is habitat quantity suitable for bull trout?	Stream length greater than or equal to neighboring systems supporting bull trout	1	X		X
		No information	0			
		Stream length less than neighboring systems supporting bull trout	-1		X	
		Maximum lake depth > 16 m	1	X	X	
		Maximum lake depth 2.2-16 m	0.5			X
		No information	0			
		Maximum lake depth < 2.2 m	-1			
		Lake surface area > 25 ha	1	X	X	X
		Lake surface area 3.4 – 25 ha	0.5			
		No information	0			
		Lake surface area < 3.4 ha	-1			

Table 5.- Physical stream characteristics by study site in Glacier National Park, Montana. Values represent the proportion of total stream area comprised of each habitat characteristic.

	Study site		
Physical habitat characteristic	Camas	Lincoln	Logging
Pool	0.06	0.13	0.18
Glide	0.42	0.09	0.17
Riffle	0.32	0.52	0.65
Cascade	0.19	0.27	0.00
Sand/silt	0.06	0.00	0.08
Gravel	0.68	0.31	0.45
Cobble	0.12	0.36	0.33
Boulder	0.09	0.19	0.14
Bedrock	0.05	0.13	0.01
Large woody debris	0.03	0.14	0.15
Undercut bank	0.01	0.00	0.02
Boulder	0.04	0.00	0.10
Overhanging vegetation	0.09	0.05	0.11
Backwater	0.00	0.00	0.04

Table 6.- Average proportion of each individual habitat unit comprised of each microhabitat type. Values represent means ± 95% CI.

	Site		
Microhabitat	Camas Creek	Lincoln Creek	Logging Creek
Substrate Type			
Sand/silt	0.07 ± 0.03	--	0.09 ± 0.03
Small gravel	0.46 ± 0.08	0.24 ± 0.14	0.17 ± 0.03
Large gravel	0.13 ± 0.04	0.10 ± 0.06	0.36 ± 0.04
Cobble	0.12 ± 0.04	0.28 ± 0.10	0.30 ± 0.03
Boulder	0.11 ± 0.03	0.11 ± 0.06	0.08 ± 0.02
Bedrock	0.11 ± 0.06	0.27 ± 0.16	< 0.01
Cover Type			
Large woody debris	0.03 ± 0.01	0.03 ± 0.04	0.28 ± 0.35
Undercut bank	< 0.01	--	0.05 ± 0.02
Boulder	0.03 ± 0.02	--	0.04 ± 0.01
Overhanging vegetation	0.10 ± 0.04	0.02 ± 0.03	0.17 ± 0.04
Backwater	0.01 ± 0.02	--	0.02 ± 0.02

Table 7.- Stream length, mean wetted width (± 95% CI), and mean pool depth (±95% CI) by study site in Glacier National Park, Montana.

	Study site		
Physical habitat characteristic	Camas	Lincoln	Logging
Stream length (m)	2,767	278	3,093
Wetted width (m)	8.1±1.5	7.0±3.0	6.0±0.6
Pool depth (m)	1.0±0.1	0.9±0.1	0.6±0.1

Table 8.- Mean August stream temperature recorded in each site during 2012.

Water Body	Study Site	Location	Mean August temperature (°C)
Camas Creek	Camas	Reach 2	15.8°C
Camas Creek	Camas	Reach 3	14.5°C
Lincoln Creek	Lincoln	Reach 3	13.5°C
Logging Creek	Logging	Reach 1	14.2°C
Logging Creek	Logging	Reach 5	10.8°C

Table 9.- Physical characteristics of lakes within each proposed site of translocation.

Water Body	Study site	Surface area (ha)	Maximum depth (m)
Camas Lake	Camas	7	9
Lake Evangeline	Camas	29	85
Lake Ellen Wilson	Lincoln	69	>90*
Grace Lake	Logging	33	15

* = Actual maximum depth not measurable due to equipment limitations.

Table 10.- Mean and maximum lake temperatures recorded in each site during August 2012. Depths of observation varied among sites to account for differences in maximum lake depth.

Water Body	Study site	Mean August temperature (°C)	Maximum August temperature (°C)	Depth of observation (m)
Camas Lake	Camas	15.9	21.7	0.6
		16.2	21.4	2.8
		15.8	19.4	4.9
		14.3	17.3	7.0
		11.8	14.9	9.1
Lake Evangeline	Camas	15.4	17.0	5.0
		9.5	12.1	10
		5.8	6.6	15
		4.6	5.2	20
		4.1	4.5	25
		4.0	4.4	30
Lake Ellen Wilson	Lincoln	14.1	17.3	0
		12.8	15.0	5
		10.1	13.1	10
		6.0	8.9	15
		5.1	6.1	20
		4.8	5.2	25
Grace Lake	Logging	14.7	15.9	2
		12.7	15.6	7
		10.1	12.2	12
		9.9	10.8	15

Table 11.- Scores for criteria used to evaluate the recipient community of each site. A score of 1 represents highly suitable habitat, a score of 0.5 represents moderately suitable habitat, and a score of -1 represents habitat of low suitability. A score of 0 indicates the information is unknown and additional research is needed.

Major Component	Question	Criteria	Score	Camas	Lincoln	Logging
Recipient Community	Adverse impacts on other sensitive aquatic species?	Threatened, endangered, or sensitive native aquatic species not detected	1		X	
		No information	0			
		Threatened, endangered, or sensitive native aquatic species detected	-1	X		X
	Compatibility with existing aquatic community?	Hybridizing or competing species not detected	1	X		X
		No information	0			
		Hybridizing or competing species detected	-1		X	

Table 12.- Aquatic specimens collected in the Camas, Lincoln, and Logging study sites, Glacier National Park, Montana. Sampling occurred between June 2010 and September 2011. An (X) represents detection of the indicated family or species in the specified site.

		Study Site		
Vertebrates		Camas	Lincoln	Logging
Brook trout *Salvelinus fontinalis*			X	
Yellowstone cutthroat trout *O. clarkii bouvieri*		X		X
Long-toed salamander *Ambystoma macrodactylum*				X
Tailed frog *Ascaphus truei*		X		
Boreal toad *Bufo boreas*		X		X
Macroinvertebrates				
Order	Family			
Amphipoda	Gammaridae	X		X
Annelida	Hirudinea	X		X
Annelida	Oligochaeta	X	X	X
Coleoptera	Dytiscidae	X		
Coleoptera	Elmidae	X		
Diptera	Athericidae			X
Diptera	Chironomidae	X	X	X
Diptera	Simuliidae			X
Diptera	Tabanidae	X		
Diptera	Tipulidae	X		X
Ephemeroptera	Baetidae	X		X
Ephemeroptera	Ephemerellidae			X
Ephemeroptera	Heptageniidae	X		X
Hemiptera	Corixidae	X		
Megaloptera	Sialidae	X	X	X
Mullusca	Sphaeriidae	X	X	
Odonata	Aeshnidae			X
Odonata	Libullulidae	X		
Plecoptera	Perlidae		X	X
Plecoptera	Perlodidae	X	X	X
Trichoptera	Hydropsychidae		X	
Trichoptera	Hydroptilidae	X		X
Trichoptera	Limnephilidae	X		
Microinvertebrates		X		X
Pyhlum	Family			
Arthropoda	Bosminidae		X	
Arthropoda	Daphniidae	X		X
Arthropoda	Centropagidae	X		
Arthropoda	Cyclopidae	X	X	X
Rotifera	Brachionidae	X		

Table 13.- Scores for criteria used to evaluate the suitability of the donor populations. A score of 1 represents a highly suitable donor population, while a score of -1 represents a donor population of low suitability. A score of 0 indicates the information is unknown and additional research is needed.

Major Component	Question	Criteria	Score	Camas	Lincoln	Logging
Donor Population	Does donor population contain sufficient adaptive potential?	Observed genetic heterozygosity ≥ 0.5	1		X	X
		No information	0			
		Observed genetic heterozygosity < 0.5	-1	X		
	Is donor population robust to removal of propagules?	*C/f* estimates ≥ 0.2 fish/net hour	1	X		
		No information	0			
		C/f estimates < 0.2 fish/net hour	-1		X	X

Table 14.- Observed heterozygosity and relative abundance (fish/net hour) of bull trout downstream of proposed translocation sites. Data collected from 2004-2006 and originally presented in Figure 7 and Table 11 from Meeuwig and Guy (2007).

Site	Lake	Observed heterozygosity	Relative abundance (fish/net hour)
Lincoln	Lincoln Lake	0.5302	0.069
Logging	Logging Lake	0.6667	0.057
Camas	Trout Lake	0.2059	0.440
Camas	Arrow Lake	0.2063	0.230

Table 15.- Major component and overall suitability scores for each site. Sites with an overall score of 0.7 – 1.0 were considered highly suitable, sites with an overall score of 0.4 – 0.69 were considered moderately suitable, and sites with an overall score below 0.4 were considered to have low suitability for bull trout translocation.

	Study Site		
Major Component	Camas	Lincoln	Logging
Recipient Habitat	0.95	0.75	0.9
Recipient Community	0	0	0
Donor Population	0	0	0
Overall Score	**0.475**	**0.375**	**0.450**

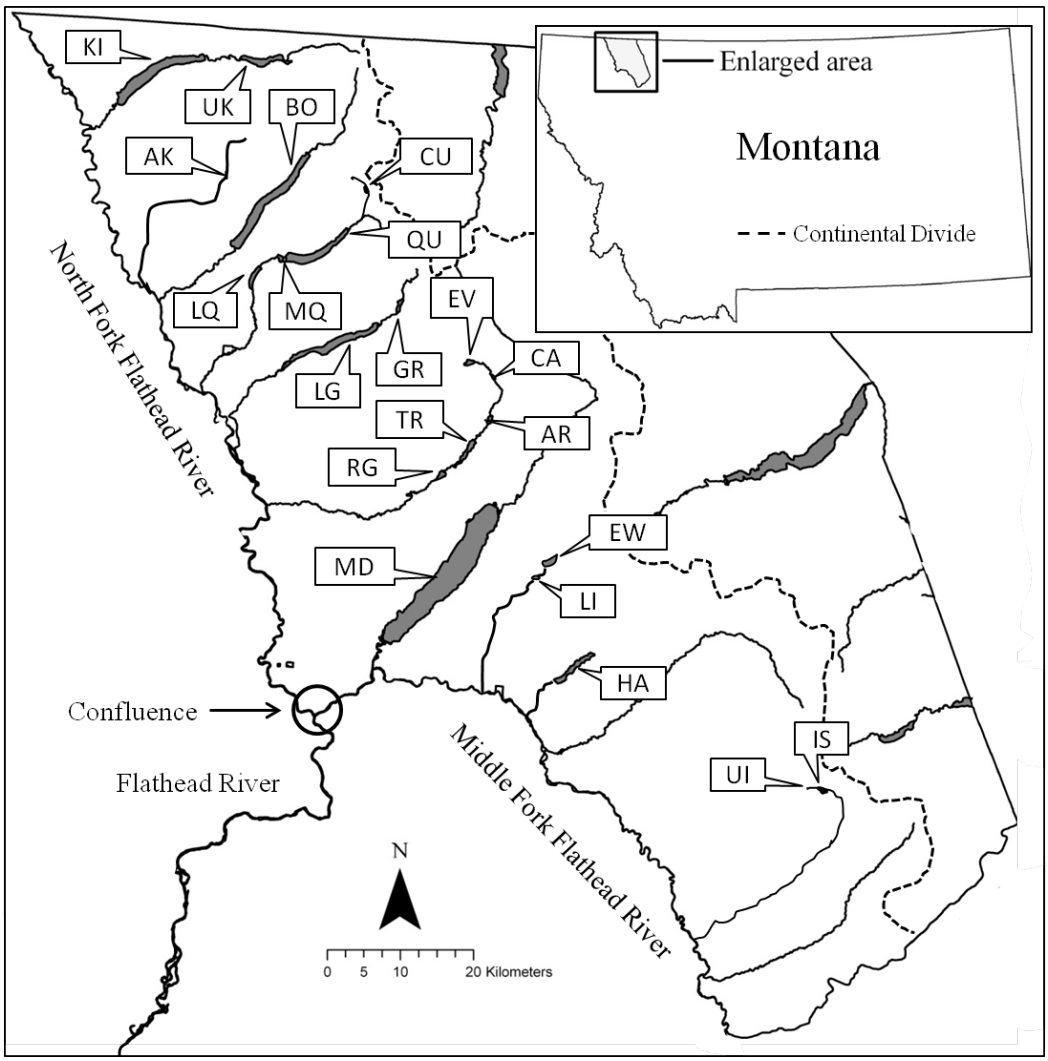


Figure 1.- Study lakes on the west side of the Continental Divide in Glacier National Park, Montana. From north to south, GR = Grace Lake, EV = Lake Evangeline, CA = Camas Lake, and EW = Lake Ellen Wilson. Seventeen additional lakes on the west side of GNP support native bull trout populations, including KI = Kintla Lake, UK = Upper Kintla Lake, AK = Akokala Lake, BO = Bowman Lake, CU = Cerulean Lake, QU = Quartz Lake, MQ = Middle Quartz Lake, LQ = Lower Quartz Lake, LG = Logging Lake, AR = Arrow Lake, TR = Trout Lake, RG = Rogers Lake, MD = Lake McDonald, LI = Lincoln Lake, HA = Harrison Lake, IS = Lake Isabel, and UI = Upper Lake Isabel.

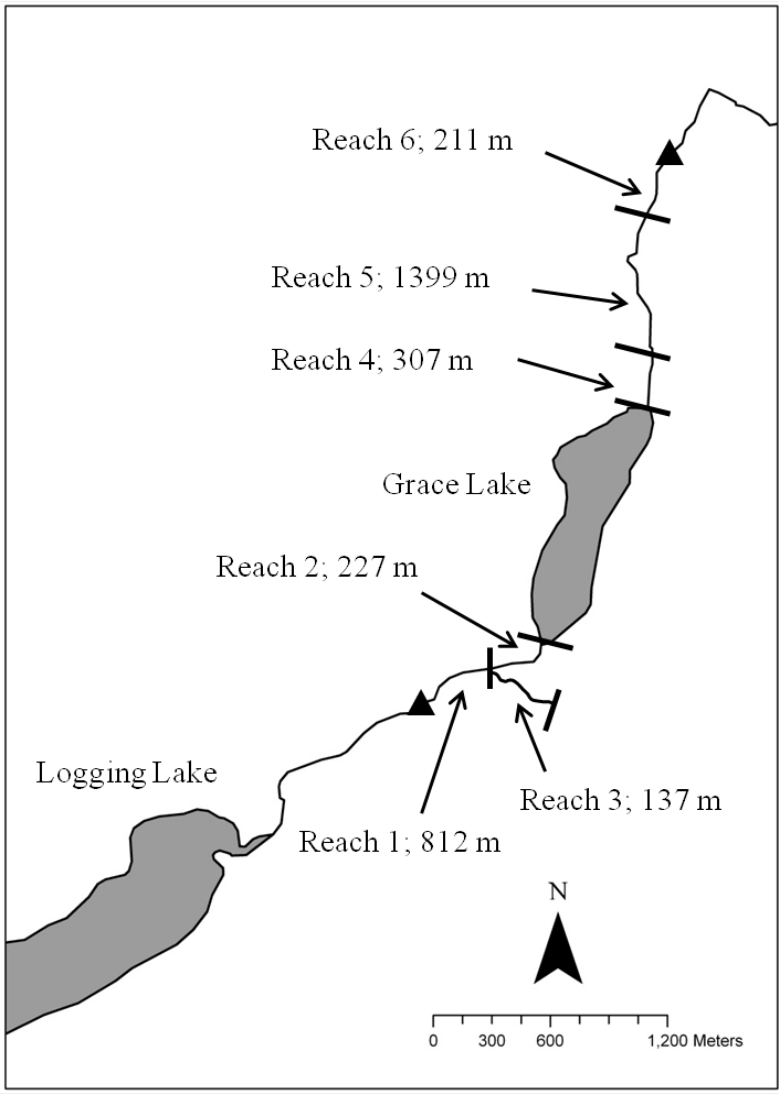


Figure 2.- Study stream reaches in the Logging site, Glacier National Park, Montana. Solid bars represent reach break points; triangles represent putative fish passage barriers.

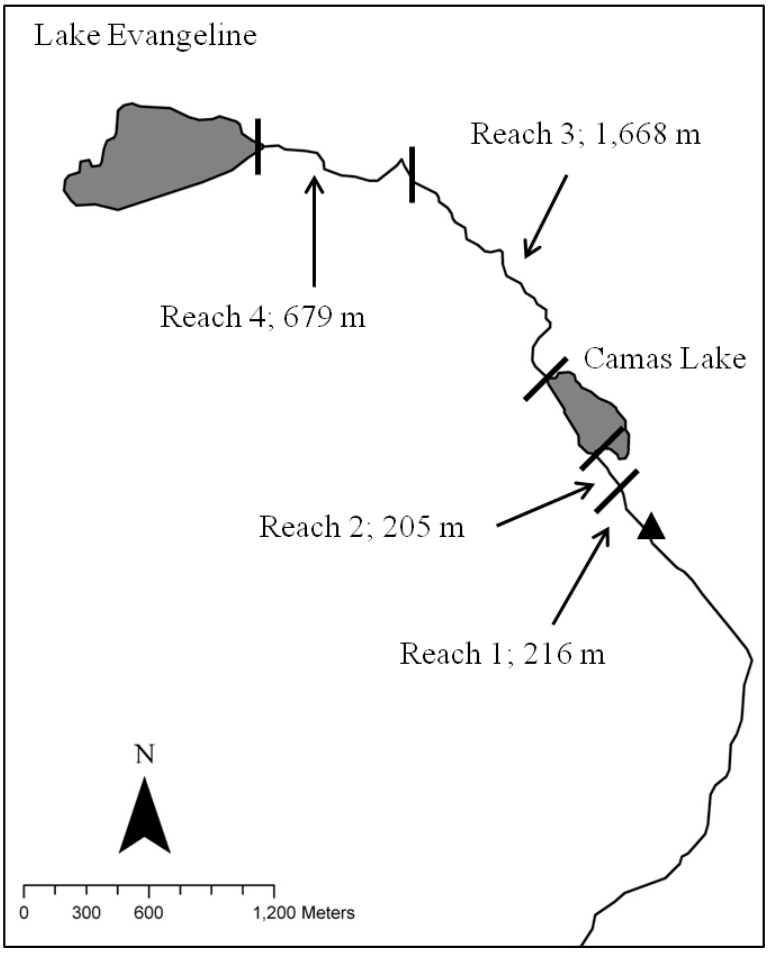


Figure 3.- Stream reaches in the Camas site, Glacier National Park, Montana. Solid bars represent reach break points; triangle represents a putative fish passage barrier.

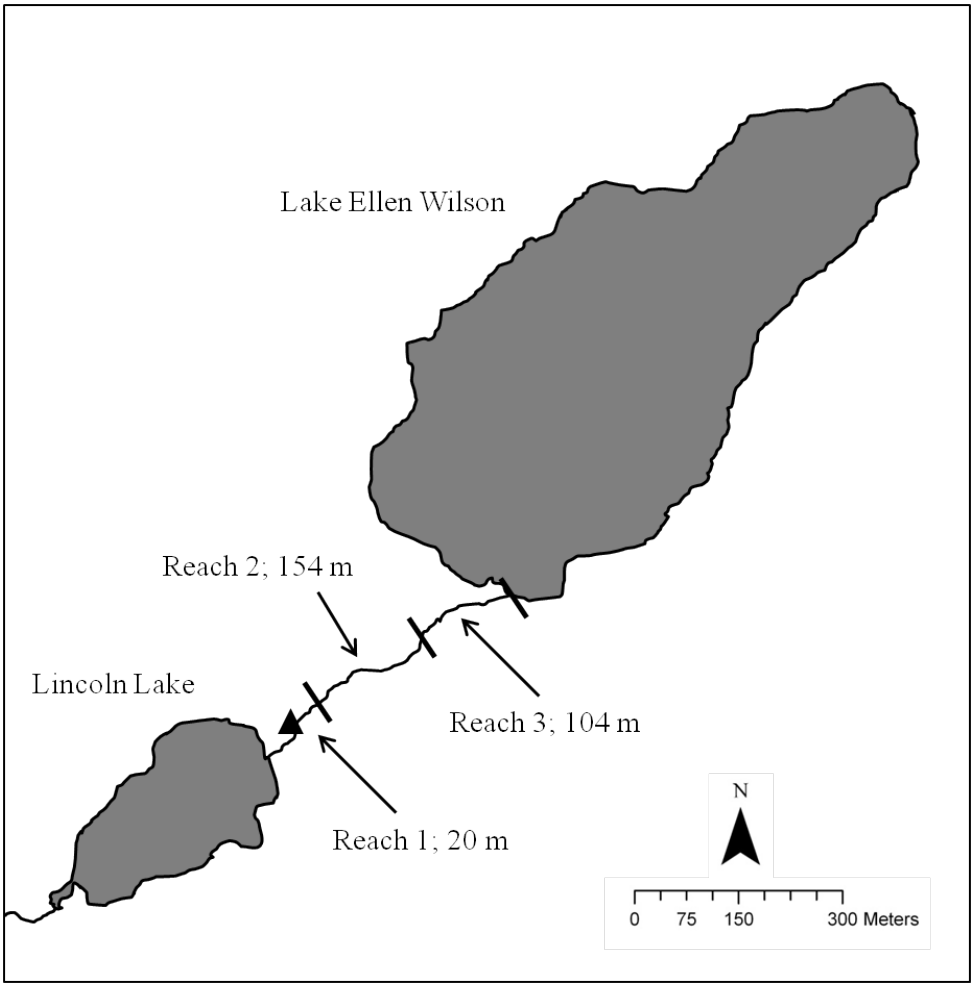


Figure 4.- Study stream reaches in the Lincoln site, Glacier National Park, Montana. Solid bars represent reach break points; triangle represents a putative fish passage barrier.

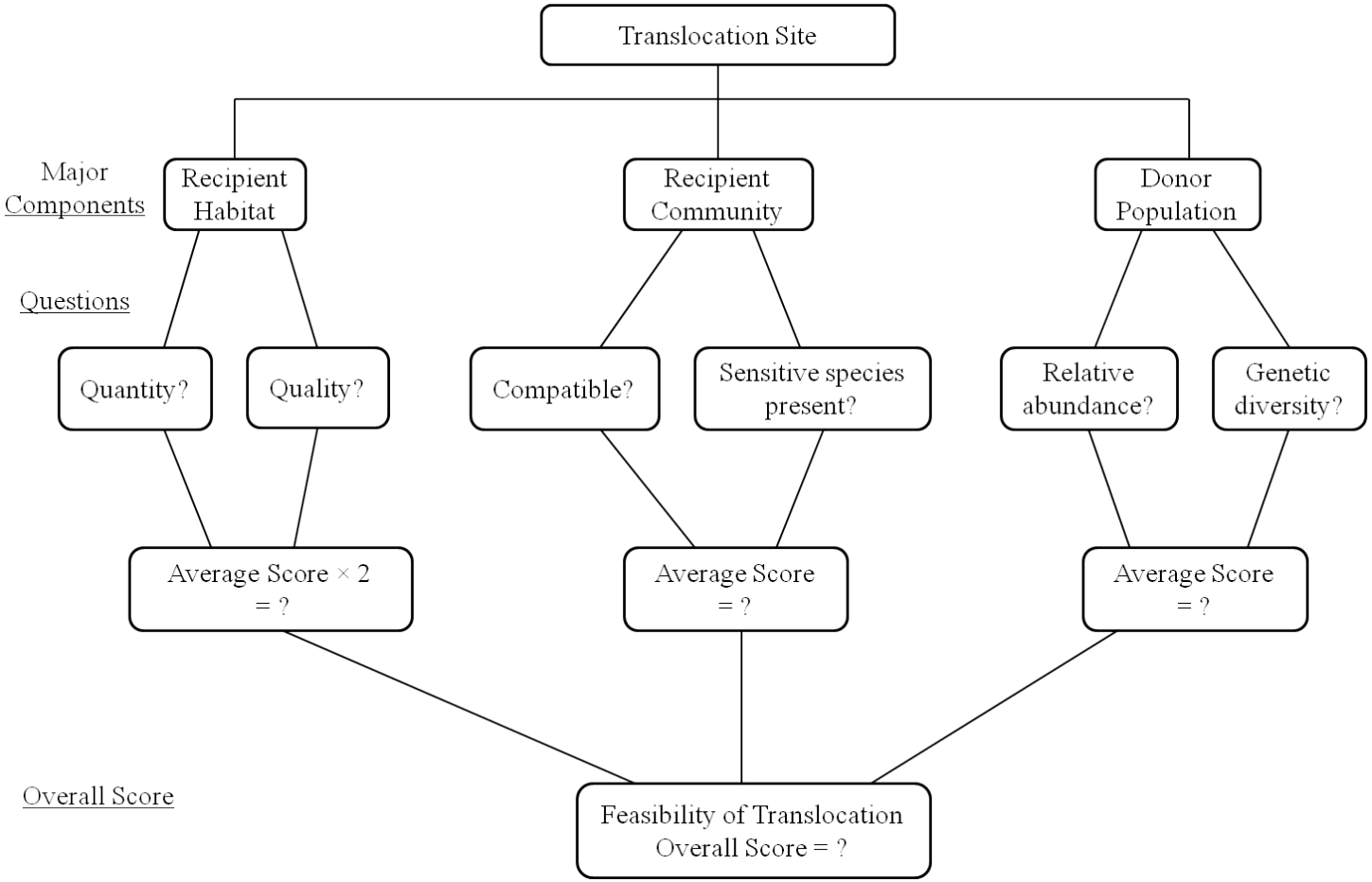


Figure 5.- Hierarchical framework to evaluate the feasibility of bull trout translocation, including three major components (recipient habitat, recipient community, and donor population) and key questions evaluating each component. Major components were scored using criteria presented in Tables 1- 3.

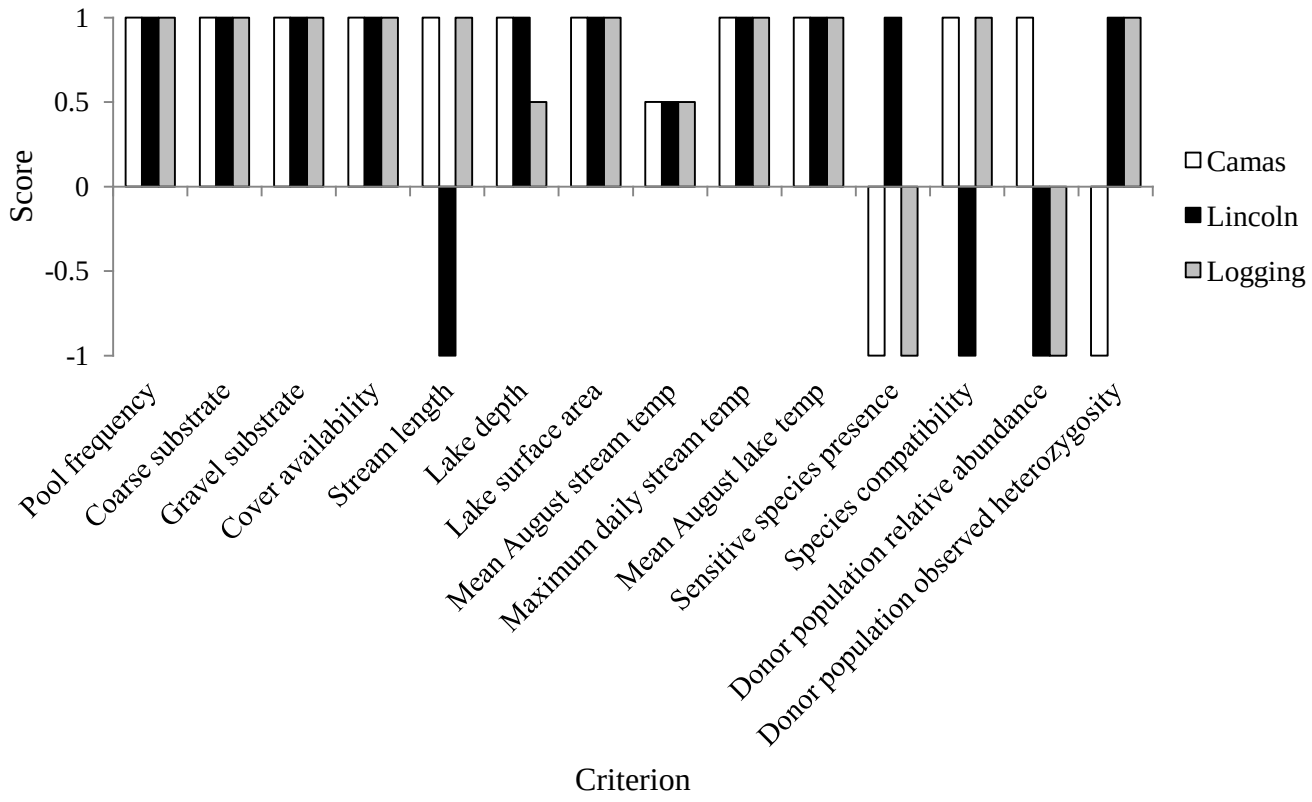


Figure 6.- Scores for individual criterion by study site.

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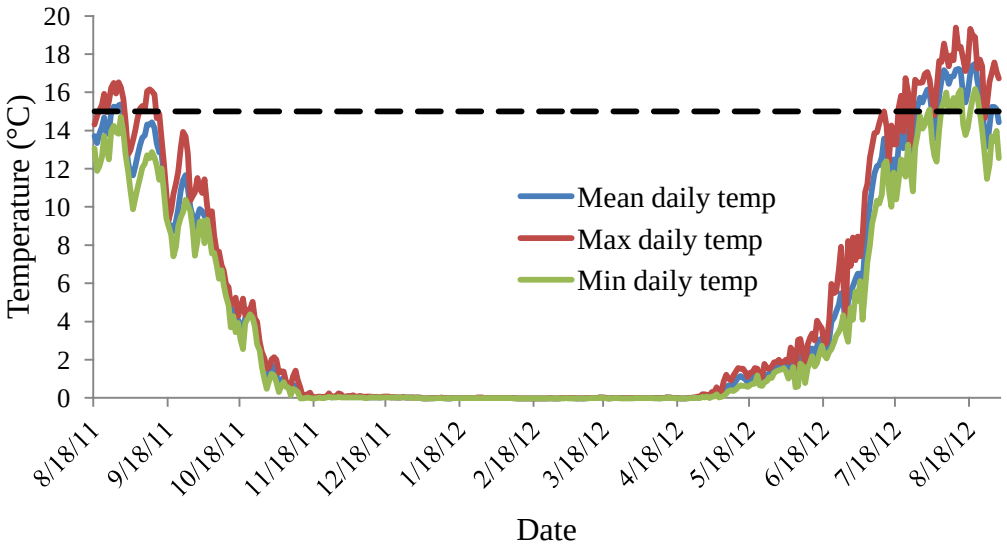
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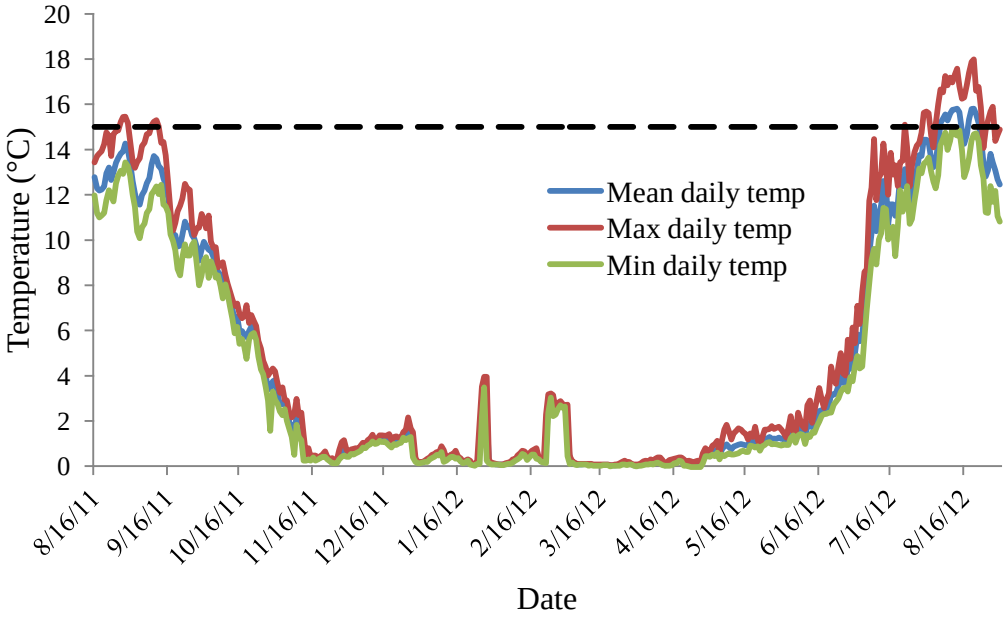
APPENDICES

APPENDIX A

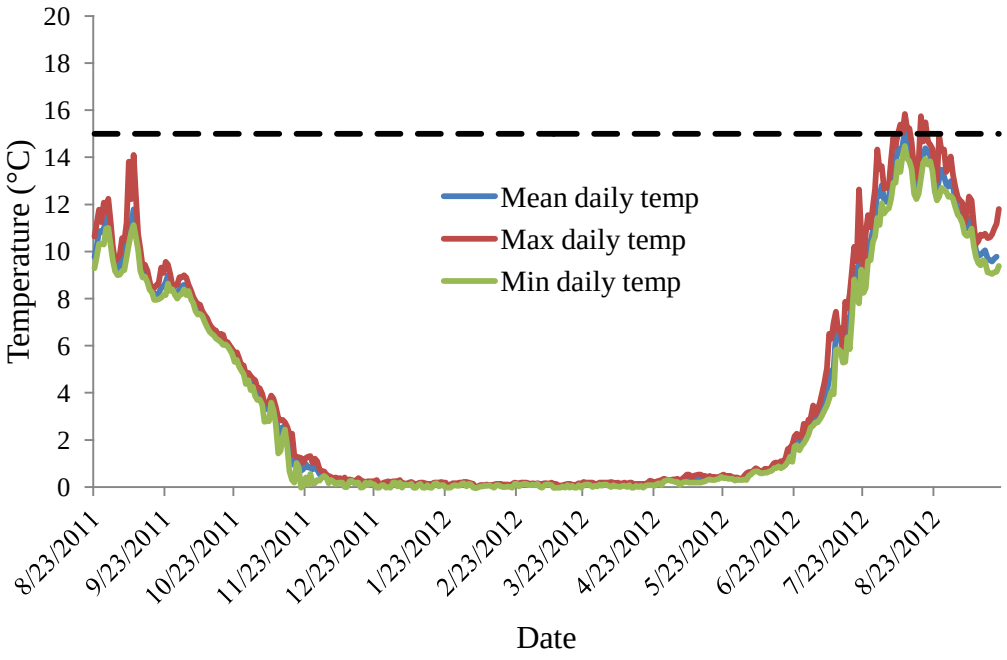
STREAM TEMPERATURE PROFILES BY REACH



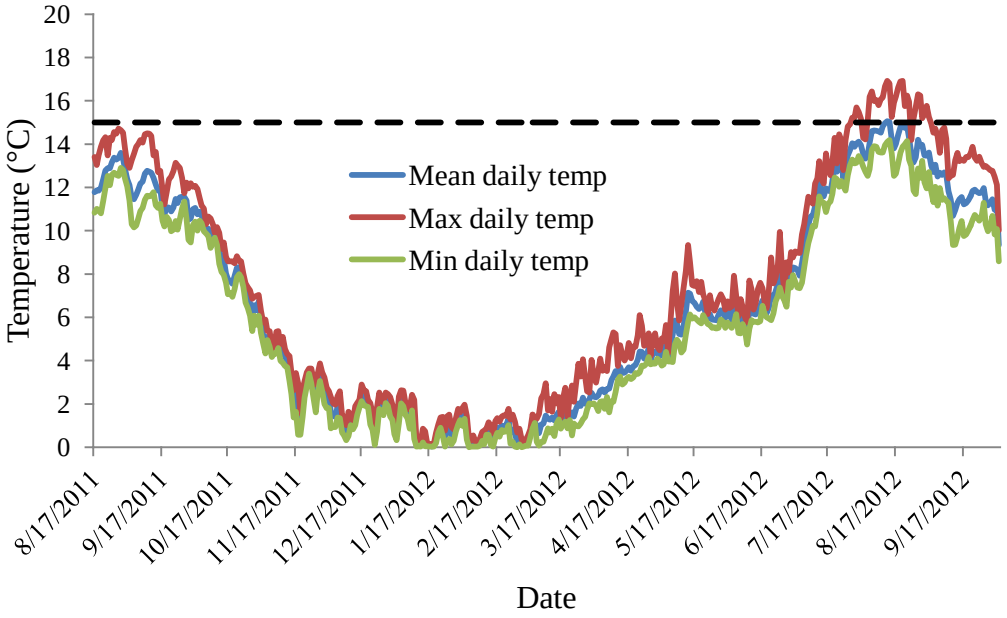
Appendix A.1.- Stream temperature (°C) in Reach 2 of Camas Creek from 18 August 2011 through 30 August 2012. The dashed line at 15°C represents the threshold used to distinguish suitable bull trout rearing habitat.



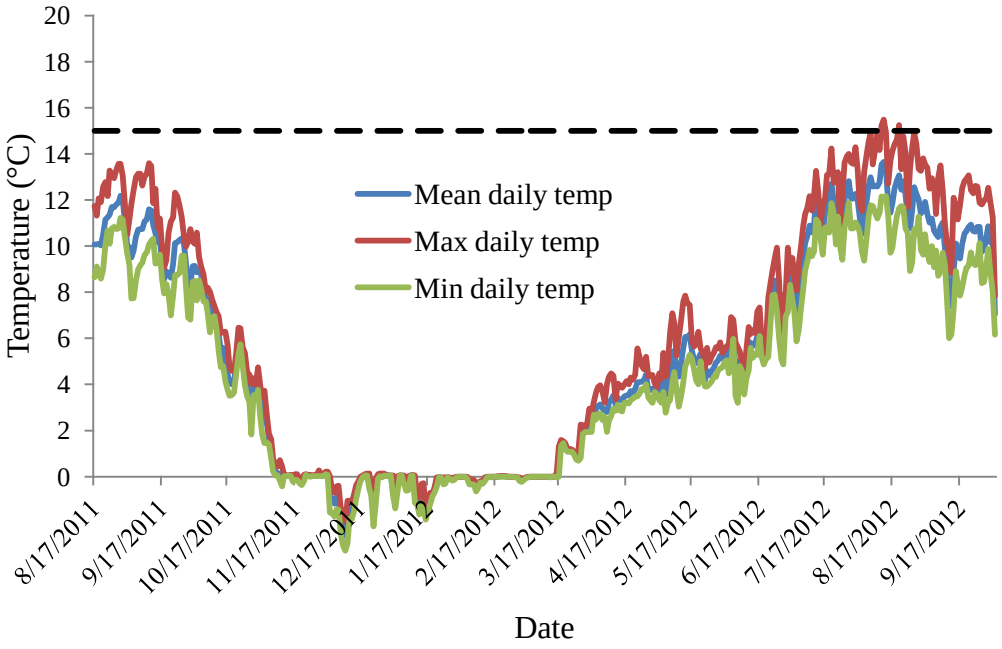
Appendix A.2.- Stream temperature (°C) in Reach 3 of Camas Creek from 16 August 2011 through 31 August 2012. The dashed line at 15°C represents the threshold used to distinguish suitable bull trout rearing habitat.



Appendix A.3.- Stream temperature (°C) in Reach 3 of Lincoln Creek from 23 August 2011 through 21 September 2012. The dashed line at 15°C represents the threshold used to distinguish suitable bull trout rearing habitat.



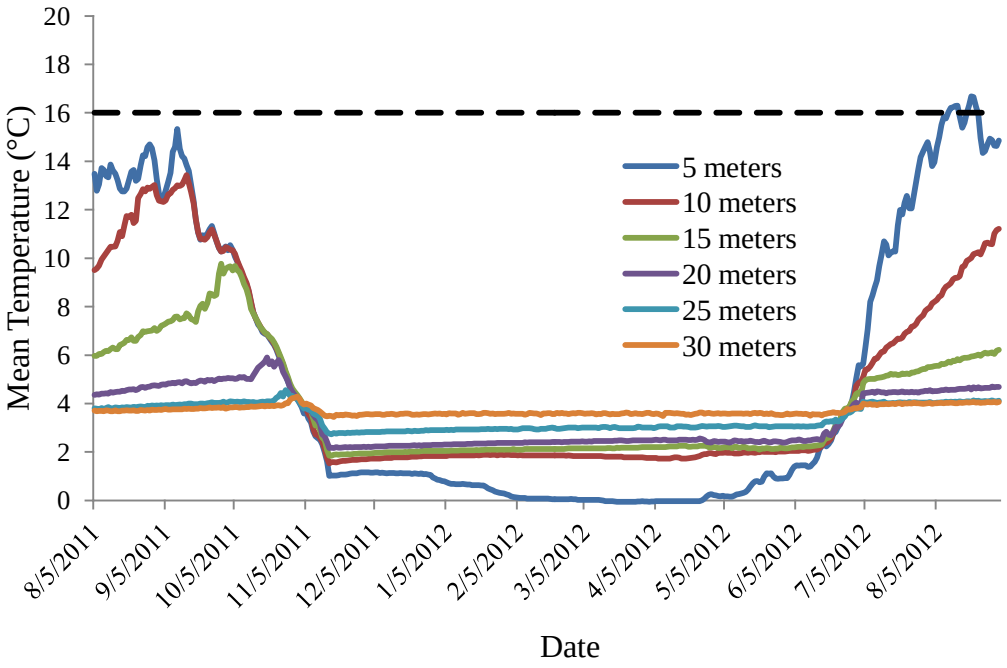
Appendix A.4.- Stream temperature (°C) in Reach 1 of Logging Creek from 17 August 2011 through 3 October 2012. The dashed line at 15°C represents the threshold used to distinguish suitable bull trout rearing habitat.



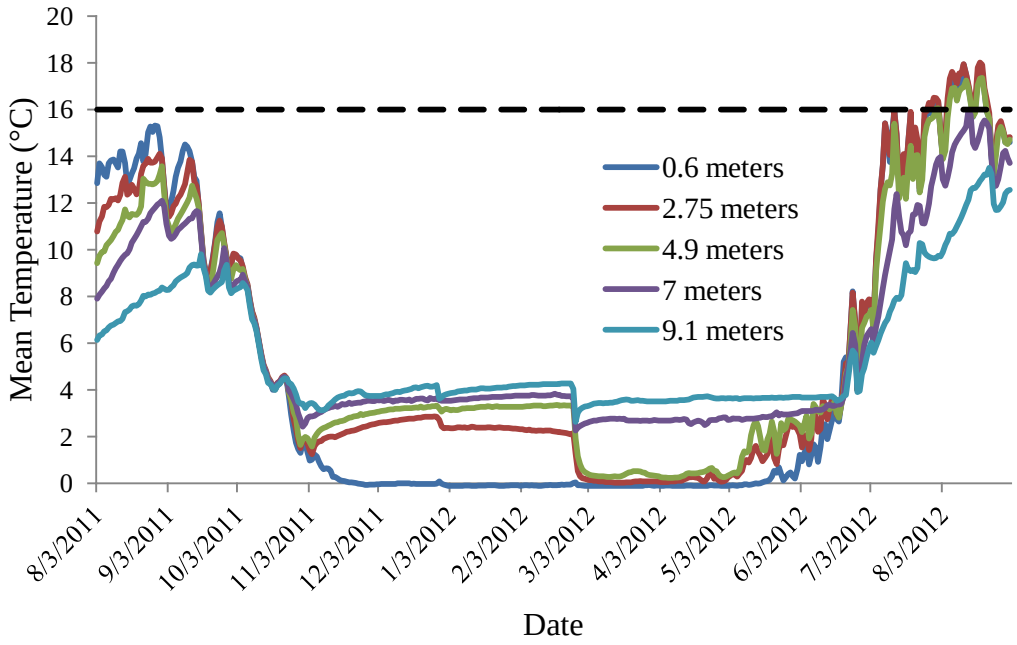
Appendix A.5.- Water temperature (°C) in Reach 5 of Logging Creek from 17 August 2011 through 3 October 2012. The dashed line at 15°C represents the threshold used to distinguish suitable bull trout rearing habitat. Negative temperatures recorded from December 1 through March 17 likely indicate the temperature logger was not submerged due to low winter flows.

APPENDIX B

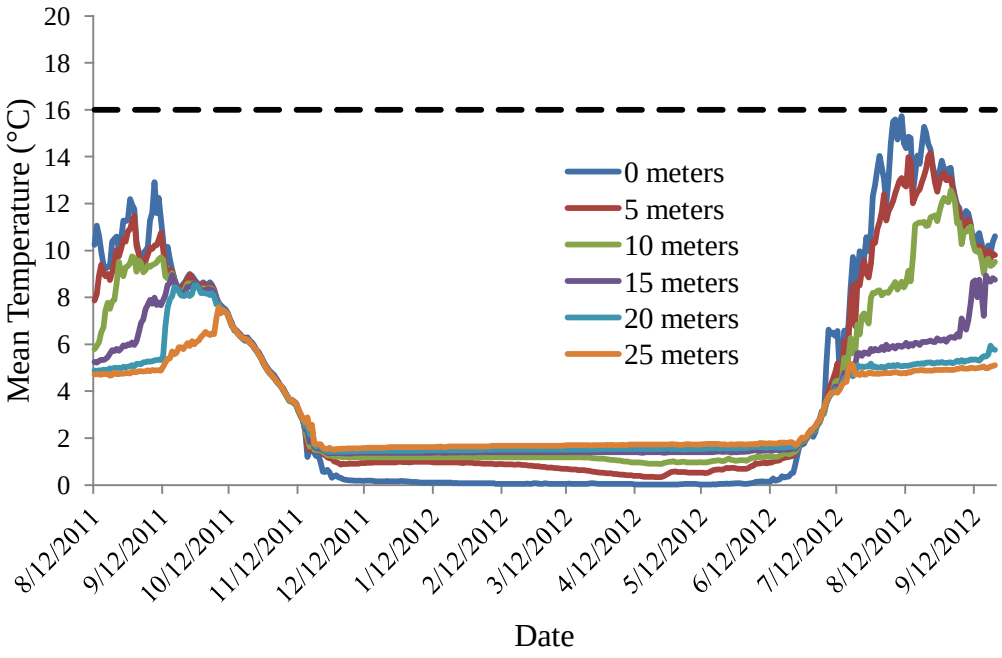
LAKE TEMPERATURE PROFILES BY DEPTH



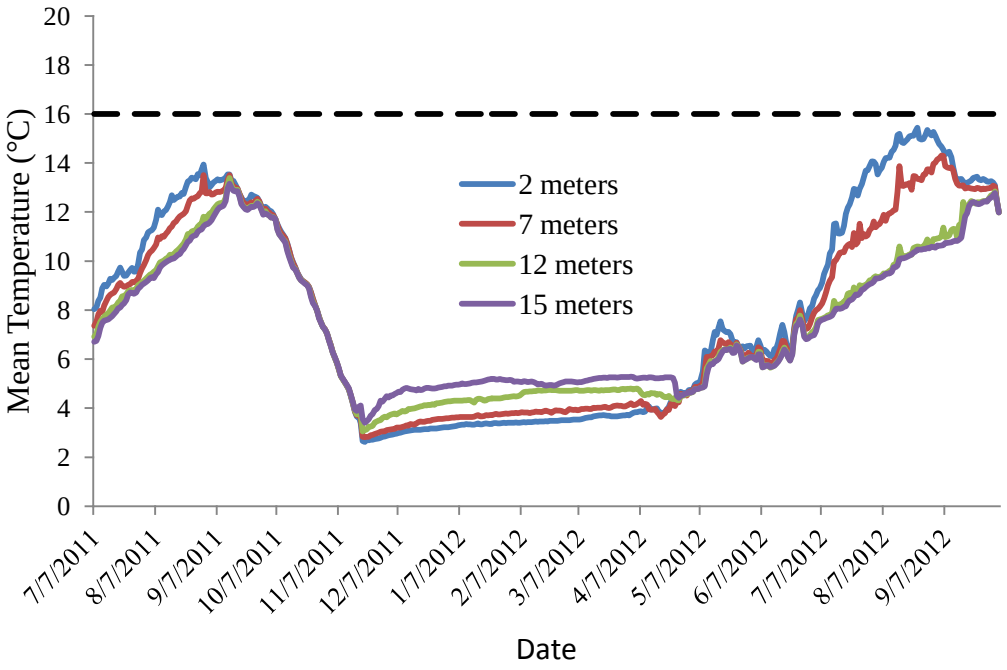
Appendix B.1.- Mean daily temperature (°C) as measured at different depths from 5 August 2011 through 1 September 2012 in Lake Evangeline. The dashed line at 16°C represents the threshold used to distinguish suitable bull trout foraging, migrating, and overwintering habitat.



Appendix B.2.- Mean daily temperature (°C) as measured at different depths from 3 August 2011 through 1 September 2012 in Camas Lake. The dashed line at 16°C represents the threshold used to distinguish suitable bull trout foraging, migrating, and overwintering habitat.



Appendix B.3.- Mean daily temperature (°C) as measured at different depths from 12 August 2011 through 21 September 2012 in Lake Ellen Wilson. The dashed line at 16°C represents the threshold used to distinguish suitable bull trout foraging, migrating, and overwintering habitat.



Appendix B.4.- Mean daily temperature (°C) as measured at different depths from 7 July 2011 through 4 October 2012 in Grace Lake. The dashed line at 16°C represents the threshold used to distinguish suitable bull trout foraging, migrating, and overwintering habitat.

APPENDIX C

ELECTROFISHING SURVEY DATA

Appendix C.- Electrofishing survey data, including water body, date and time of survey, unit length and width, unit designation, shock time, and number and species of fish captured.

Water body	Date	Time	Unit Length (m)	Unit Width (m)	Slow/fast	Shock time (sec)	YCT	BKT
Camas Creek	8/16/2011	1200	26	4.8	slow	116	0	
Camas Creek	8/16/2011	1315	10.3	6.2	slow	52	0	
Camas Creek	8/16/2011	1400	16.7	6.2	slow	58	0	
Camas Creek	8/16/2011	1445	8.4	6	slow	59	1	
Camas Creek	8/16/2011	1500	68.7	6.4	fast	312	4	
Camas Creek	8/17/2011	1110	25.1	6.3	slow	93	1	
Camas Creek	8/17/2011	1125	41.6	4.7	fast	129	0	
Camas Creek	8/17/2011	1300	6.3	5.9	slow	32	0	
Camas Creek	8/17/2011	1320	8.3	5.5	fast	36	0	
Camas Creek	8/18/2011	930	10.2	25.6	fast	131	0	
Camas Creek	8/18/2011	945	10.2	4.4	slow	68	0	
Camas Creek	8/18/2011	1230	34.6	15.9	slow	69	0	
Camas Creek	8/18/2011	1240	12.5	11.5	fast	74	0	
Camas Creek	8/18/2011	1300	70.5	11.1	fast	110	0	
Camas Creek	8/18/2011	1310	23.9	10.6	slow	122	0	
Camas Lake	8/18/2011	1320	50	N/A	N/A	189	0	
Camas Lake	8/18/2011	1330	50	N/A	N/A	220	0	
Camas Lake	8/18/2011	1345	50	N/A	N/A	175	0	
Camas Lake	8/18/2011	1400	50	N/A	N/A	181	0	
Lake Evangeline	8/17/2011	1400	50	N/A	N/A	88	0	
Lake Evangeline	8/17/2011	1340	50	N/A	N/A	98	0	
Lake Evangeline	8/17/2011	1440	50	N/A	N/A	89	0	
Lake Evangeline	8/17/2011	1500	50	N/A	N/A	97	0	
Lincoln Creek	8/23/2011	1430	11.9	8.8	slow	69	N/A	0
Lincoln Creek	8/23/2011	1440	15.2	5	fast	63	N/A	0

Appendix C continued.

Water body	Date	Time	Unit Length (m)	Unit Width (m)	Slow/fast	Shock time (sec)	YCT	BKT
Lincoln Creek	8/23/2011	1455	17.6	8	slow	112	N/A	2
Lincoln Creek	8/23/2011	1510	6.8	5.5	fast	49	N/A	0
Lake Ellen Wilson	8/23/2011	1015	50	N/A	N/A	201	N/A	2
Lake Ellen Wilson	8/23/2011	1830	50	N/A	N/A	189	N/A	3
Lake Ellen Wilson	8/22/2011	1900	50	N/A	N/A	187	N/A	0
Lake Ellen Wilson	8/23/2011	1400	50	N/A	N/A	103	N/A	2
Logging Creek	8/24/2010	1007	19.6	8.4	fast	168	0	
Logging Creek	8/24/2010	1015	11.5	8.7	slow	155	0	
Logging Creek	8/24/2010	1048	19.2	6	slow	133	0	
Logging Creek	8/24/2010	1052	8.4	7.6	fast	111	3	
Logging Creek	8/24/2010	1135	29	5.5	slow	227	1	
Logging Creek	8/24/2010	115	20.3	8.3	fast	187	1	
Logging Creek	8/24/2010	1205	5.6	4.8	slow	77	0	
Logging Creek	8/24/2010	1210	15.1	6.9	fast	127	0	
Logging Creek	8/24/2010	1235	11.9	3.9	fast	123	2	
Logging Creek	8/24/2010	1240	2.1	2.8	slow	40	1	
Logging Creek	8/24/2010	1300	15.8	4.2	slow	101	0	
Logging Creek	8/24/2010	1305	8.8	2.8	fast	59	0	
Logging Creek	8/24/2010	1310	3.1	4.6	slow	60	1	
Logging Creek	8/24/2010	1345	7.2	7	slow	80	0	
Logging Creek	8/24/2010	1415	85.7	22.5	fast	473	3	

Appendix C continued.

Water body	Date	Time	Unit Length (m)	Unit Width (m)	Slow/fast	Shock time (sec)	YCT	BKT
Logging Creek	8/25/2010	1000	22	10.8	slow	143	2	
Logging Creek	8/25/2010	1010	27.5	11.9	fast	171	1	
Logging Creek	8/25/2010	1025	78.4	25	fast	323	4	
Logging Creek	8/25/2010	1030	39.1	17.3	slow	126	1	
Logging Creek	8/25/2010	1145	N/A	N/A	slow	48	0	
Logging Creek	8/25/2010	1200	N/A	N/A	fast	52	0	
Logging Creek	8/25/2010	1220	N/A	N/A	slow	58	1	
Logging Creek	8/25/2010	1230	N/A	N/A	fast	66	1	
Logging Creek	8/25/2010	1300	17.3	7.3	slow	101	1	
Logging Creek	8/25/2010	1310	44.8	7.1	fast	308	2	
Logging Creek	8/25/2010	1330	13.7	5.2	slow	139	6	
Logging Creek	8/25/2010	1355	80.3	12.6	fast	326	5	
Logging Creek	8/25/2010	1410	10.9	8.7	slow	132	2	
Logging Creek	8/25/2010	1415	5.1	2.9	fast	23	0	
Logging Creek	8/25/2010	1435	N/A	N/A	fast	156	2	
Logging Creek	8/25/2010	1445	N/A	N/A	slow	38	0	
Logging Creek	8/25/2010	1505	N/A	N/A	slow	110	2	
Logging Creek	8/25/2010	1515	N/A	N/A	fast	89	0	
Logging Creek	8/25/2010	1535	9.2	3.5	fast	33	0	
Logging Creek	8/25/2010	1545	7.8	4.5	slow	85	2	
Grace Lake	7/6/2011	1155	70	N/A	N/A	448	0	
Grace Lake	7/6/2011	1355	65	N/A	N/A	350	0	
Grace Lake	7/6/2011	1450	60	N/A	N/A	349	0	
Grace Lake	7/6/2011	1600	85	N/A	N/A	428	1	
Grace Lake	7/6/2011	1700	55	N/A	N/A	235	0	

APPENDIX D

ELECTROFISHING CATCH DATA

Appendix D.- Catch data for electrofishing surveys conducted, including site, water body, and species and length of fish captured.

		Length (mm)	
Site	Water Body	YCT	BKT
Camas	Camas Creek	56	
Camas	Camas Creek	128	
Camas	Camas Creek	52	
Camas	Camas Creek	68	
Camas	Camas Creek	56	
Camas	Camas Creek	122	
Lincoln	Lincoln Creek		295
Lincoln	Lincoln Creek		287
Lincoln	Lake Ellen Wilson		175
Lincoln	Lake Ellen Wilson		29
Lincoln	Lake Ellen Wilson		146
Lincoln	Lake Ellen Wilson		57
Lincoln	Lake Ellen Wilson		21
Lincoln	Lake Ellen Wilson		98
Lincoln	Lake Ellen Wilson		77
Logging	Grace Lake	95	
Logging	Logging Creek	132	
Logging	Logging Creek	136	
Logging	Logging Creek	107	
Logging	Logging Creek	191	
Logging	Logging Creek	115	
Logging	Logging Creek	90	
Logging	Logging Creek	75	
Logging	Logging Creek	90	
Logging	Logging Creek	92	
Logging	Logging Creek	210	
Logging	Logging Creek	98	
Logging	Logging Creek	104	
Logging	Logging Creek	340	
Logging	Logging Creek	145	
Logging	Logging Creek	85	
Logging	Logging Creek	165	
Logging	Logging Creek	90	
Logging	Logging Creek	95	
Logging	Logging Creek	85	
Logging	Logging Creek	55	

Appendix D continued.

		Length (mm)	
Site	Water Body	YCT	BKT
Logging	Logging Creek	120	
Logging	Logging Creek	160	
Logging	Logging Creek	160	
Logging	Logging Creek	110	
Logging	Logging Creek	95	
Logging	Logging Creek	85	
Logging	Logging Creek	90	
Logging	Logging Creek	100	
Logging	Logging Creek	122	
Logging	Logging Creek	106	
Logging	Logging Creek	86	
Logging	Logging Creek	71	
Logging	Logging Creek	110	
Logging	Logging Creek	105	
Logging	Logging Creek	104	
Logging	Logging Creek	80	
Logging	Logging Creek	59	
Logging	Logging Creek	60	
Logging	Logging Creek	85	
Logging	Logging Creek	85	
Logging	Logging Creek	94	
Logging	Logging Creek	158	
Logging	Logging Creek	78	
Logging	Logging Creek	117	

APPENDIX E

GILL NETTING SURVEY DATA

Appendix E.- Gill netting survey data, including water body, set and pull date and time, soak time, net orientation, depth of set, and number and species of fish captured.

Water Body	Set Date	Set Time	Pull Date	Pull Time	Soak Time (min)	Orientation	Start Depth (m)	End Depth (m)	YCT	BKT
Grace Lake	8/3/2010	943	8/3/2010	1043	60	large mesh on shore	0.0	5.5	3	
Grace Lake	8/3/2010	1829	8/3/2010	1929	60	large mesh on shore	0.0	4.9	6	
Grace Lake	8/4/2010	809	8/4/2010	906	57	large mesh on shore	2.6	8.9	5	
Grace Lake	8/4/2010	1925	8/5/2010	853	808	small mesh on shore	0.0	7.3	11	
Lake Ellen Wilson	8/10/2011	830	8/10/2011	930	60	small mesh on shore	2.4	4.9		3
Lake Ellen Wilson	8/10/2011	1000	8/10/2011	1100	60	large mesh on shore	0.0	4.9		0
Lake Ellen Wilson	8/10/2011	1130	8/10/2011	1230	60	small mesh on shore	0.0	5.8		8
Lake Ellen Wilson	8/10/2011	2030	8/11/2011	800	690	large mesh on shore	0.0	2.1		45
Camas Lake	8/1/2011	2035	8/2/2011	825	710	large mesh on shore	0.0	7.6	8	
Camas Lake	8/2/2011	833	8/2/2011	1028	115	small mesh on shore	0.0	3.4	0	
Camas Lake	8/2/2011	1100	8/2/2011	1215	75	large mesh on shore	0.0	0.9	0	
Camas Lake	8/2/2011	1245	8/2/2011	1345	60	small mesh on shore	0.0	2.4	0	
Lake Evangeline	8/3/2011	1220	8/3/2011	1340	80	large mesh on shore	0.0	3.7	2	
Lake Evangeline	8/3/2011	1440	8/3/2011	1545	65	small mesh on shore	0.0	4.2	0	
Lake Evangeline	8/3/2011	1610	8/3/2011	1710	60	large mesh on shore	0.0	14.9	3	
Lake Evangeline	8/3/2011	1735	8/4/2011	925	950	small mesh on shore	0.0	2.4	9	

APPENDIX F

GILL NETTING CATCH DATA

Appendix F.- Gill netting catch data, including site, water body, and species and length of fish captured.

			Length (mm)	
Site	Water Body	Gear type	YCT	BKT
Camas	Camas Lake	Gill Net	192	
Camas	Camas Lake	Gill Net	225	
Camas	Camas Lake	Gill Net	281	
Camas	Camas Lake	Gill Net	282	
Camas	Camas Lake	Gill Net	241	
Camas	Camas Lake	Gill Net	269	
Camas	Camas Lake	Gill Net	156	
Camas	Camas Lake	Gill Net	301	
Camas	Lake Evangeline	Gill Net	298	
Camas	Lake Evangeline	Gill Net	212	
Camas	Lake Evangeline	Gill Net	277	
Camas	Lake Evangeline	Gill Net	289	
Camas	Lake Evangeline	Gill Net	304	
Camas	Lake Evangeline	Gill Net	179	
Camas	Lake Evangeline	Gill Net	223	
Camas	Lake Evangeline	Gill Net	281	
Camas	Lake Evangeline	Gill Net	280	
Camas	Lake Evangeline	Gill Net	254	
Camas	Lake Evangeline	Gill Net	291	
Camas	Lake Evangeline	Gill Net	266	
Camas	Lake Evangeline	Gill Net	231	
Camas	Lake Evangeline	Gill Net	293	
Lincoln	Lake Ellen Wilson	Gill Net		190
Lincoln	Lake Ellen Wilson	Gill Net		252
Lincoln	Lake Ellen Wilson	Gill Net		280
Lincoln	Lake Ellen Wilson	Gill Net		310
Lincoln	Lake Ellen Wilson	Gill Net		185
Lincoln	Lake Ellen Wilson	Gill Net		293
Lincoln	Lake Ellen Wilson	Gill Net		275
Lincoln	Lake Ellen Wilson	Gill Net		240
Lincoln	Lake Ellen Wilson	Gill Net		301
Lincoln	Lake Ellen Wilson	Gill Net		191
Lincoln	Lake Ellen Wilson	Gill Net		201
Lincoln	Lake Ellen Wilson	Gill Net		151
Lincoln	Lake Ellen Wilson	Gill Net		199
Lincoln	Lake Ellen Wilson	Gill Net		235

Appendix F continued.

			Length (mm)	
Site	Water Body	Gear type	YCT	BKT
Lincoln	Lake Ellen Wilson	Gill Net		266
Lincoln	Lake Ellen Wilson	Gill Net		277
Lincoln	Lake Ellen Wilson	Gill Net		301
Lincoln	Lake Ellen Wilson	Gill Net		268
Lincoln	Lake Ellen Wilson	Gill Net		310
Lincoln	Lake Ellen Wilson	Gill Net		177
Lincoln	Lake Ellen Wilson	Gill Net		302
Lincoln	Lake Ellen Wilson	Gill Net		257
Lincoln	Lake Ellen Wilson	Gill Net		259
Lincoln	Lake Ellen Wilson	Gill Net		291
Lincoln	Lake Ellen Wilson	Gill Net		273
Lincoln	Lake Ellen Wilson	Gill Net		251
Lincoln	Lake Ellen Wilson	Gill Net		288
Lincoln	Lake Ellen Wilson	Gill Net		281
Lincoln	Lake Ellen Wilson	Gill Net		262
Lincoln	Lake Ellen Wilson	Gill Net		280
Lincoln	Lake Ellen Wilson	Gill Net		197
Lincoln	Lake Ellen Wilson	Gill Net		280
Lincoln	Lake Ellen Wilson	Gill Net		190
Lincoln	Lake Ellen Wilson	Gill Net		290
Lincoln	Lake Ellen Wilson	Gill Net		211
Lincoln	Lake Ellen Wilson	Gill Net		221
Lincoln	Lake Ellen Wilson	Gill Net		257
Lincoln	Lake Ellen Wilson	Gill Net		223
Lincoln	Lake Ellen Wilson	Gill Net		241
Lincoln	Lake Ellen Wilson	Gill Net		282
Lincoln	Lake Ellen Wilson	Gill Net		276
Lincoln	Lake Ellen Wilson	Gill Net		247
Lincoln	Lake Ellen Wilson	Gill Net		250
Lincoln	Lake Ellen Wilson	Gill Net		228
Lincoln	Lake Ellen Wilson	Gill Net		276
Lincoln	Lake Ellen Wilson	Gill Net		260
Lincoln	Lake Ellen Wilson	Gill Net		256
Lincoln	Lake Ellen Wilson	Gill Net		297
Lincoln	Lake Ellen Wilson	Gill Net		208
Lincoln	Lake Ellen Wilson	Gill Net		274
Lincoln	Lake Ellen Wilson	Gill Net		265

Appendix F continued.

			Length (mm)	
Site	Water Body	Gear type	YCT	BKT
Lincoln	Lake Ellen Wilson	Gill Net		209
Lincoln	Lake Ellen Wilson	Gill Net		212
Lincoln	Lake Ellen Wilson	Gill Net		215
Lincoln	Lake Ellen Wilson	Gill Net		278
Lincoln	Lake Ellen Wilson	Gill Net		306
Logging	Grace Lake	Gill Net	275	
Logging	Grace Lake	Gill Net	349	
Logging	Grace Lake	Gill Net	408	
Logging	Grace Lake	Gill Net	248	
Logging	Grace Lake	Gill Net	241	
Logging	Grace Lake	Gill Net	322	
Logging	Grace Lake	Gill Net	277	
Logging	Grace Lake	Gill Net	276	
Logging	Grace Lake	Gill Net	370	
Logging	Grace Lake	Gill Net	328	
Logging	Grace Lake	Gill Net	326	
Logging	Grace Lake	Gill Net	337	
Logging	Grace Lake	Gill Net	352	
Logging	Grace Lake	Gill Net	355	
Logging	Grace Lake	Gill Net	304	
Logging	Grace Lake	Gill Net	371	
Logging	Grace Lake	Gill Net	357	
Logging	Grace Lake	Gill Net	361	
Logging	Grace Lake	Gill Net	324	
Logging	Grace Lake	Gill Net	381	
Logging	Grace Lake	Gill Net	309	
Logging	Grace Lake	Gill Net	258	
Logging	Grace Lake	Gill Net	311	
Logging	Grace Lake	Gill Net	260	
Logging	Grace Lake	Gill Net	192	

APPENDIX G

INVERTEBRATE SAMPLING DATA

Appendix G.- Invertebrate sampling data, including site, water body, date and time of sample, general location, unit designation, and depth of sample.

Site	Water Body	Date	Time	Location	Slow/Fast/ Shoreline	Depth (m)
Camas	Camas Creek	8/16/2011	1205	reach 1	fast	0.46
Camas	Camas Creek	8/16/2011	1210	reach 1	slow	0.61
Camas	Camas Creek	8/17/2011	1032	reach 2	fast	0.30
Camas	Camas Creek	8/17/2011	1040	reach 2	slow	0.46
Camas	Camas Creek	8/18/2011	1000	reach 3	fast	0.46
Camas	Camas Creek	8/18/2011	1015	reach 3	slow	0.46
Camas	Camas Lake	8/2/2011	1107	E shore	shoreline	0.30
Camas	Camas Lake	8/2/2011	1121	N shore	shoreline	0.30
Camas	Camas Lake	8/2/2011	1325	S shore	shoreline	0.30
Camas	Camas Lake	8/2/2011	1445	S shore	shoreline	0.20
Camas	Camas Lake	8/2/2011	1505	E shore	shoreline	0.20
Camas	Camas Lake	8/2/2011	1600	W shore	shoreline	0.20
Camas	Lake Evangeline	8/3/2011	1245	W shore	shoreline	0.30
Camas	Lake Evangeline	8/3/2011	1335	N shore	shoreline	0.46
Camas	Lake Evangeline	8/3/2011	1425	E shore	shoreline	0.15
Camas	Lake Evangeline	8/3/2011	1445	E shore	shoreline	0.30
Camas	Lake Evangeline	8/3/2011	1510	S shore	shoreline	0.46
Camas	Lake Evangeline	8/3/2011	1530	S shore	shoreline	0.30
Lincoln	Lincoln Creek	8/23/2011	1100	reach 3	slow	0.61
Lincoln	Lincoln Creek	8/23/2011	1115	reach 3	fast	0.30
Lincoln	Lincoln Creek	8/23/2011	1210	reach 2	slow	0.46
Lincoln	Lincoln Creek	8/23/2011	1220	reach 2	fast	0.30
Lincoln	Lake Ellen Wilson	8/22/2011	1745	N shore	shoreline	0.61
Lincoln	Lake Ellen Wilson	8/22/2011	1815	E shore	shoreline	0.46
Lincoln	Lake Ellen Wilson	8/22/2011	1920	N shore	shoreline	0.61
Lincoln	Lake Ellen Wilson	8/23/2011	1000	S shore	shoreline	0.30
Lincoln	Lake Ellen Wilson	8/23/2011	1400	S shore	shoreline	0.46
Logging	Logging Creek	8/4/2010	1312	reach 1	fast	0.30
Logging	Logging Creek	8/4/2010	1320	reach 1	slow	0.30
Logging	Logging Creek	8/5/2010	1145	reach 2	fast	0.30
Logging	Logging Creek	8/5/2010	1200	reach 2	slow	0.30
Logging	Logging Creek	8/5/2010	1440	reach 5	fast	0.08
Logging	Logging Creek	8/5/2010	1445	reach 5	slow	0.30
Logging	Logging Creek	8/5/2010	1510	reach 4	fast	0.15
Logging	Logging Creek	8/5/2010	1515	reach 4	slow	0.30
Logging	Grace Lake	8/4/2010	1700	S shore	shoreline	0.46

Appendix G continued.

Site	Water Body	Date	Time	Location	Slow/Fast/ Shoreline	Depth (m)
Logging	Grace Lake	8/4/2010	1730	W shore	shoreline	0.30
Logging	Grace Lake	8/3/2010	1100	N shore	shoreline	0.30
Logging	Grace Lake	8/3/2010	1145	E shore	shoreline	0.30

APPENDIX H

ZOOPLANKTON SAMPLING DATA

Appendix H.- Zooplankton sampling data, including water body, date and time of sample, and depth where sample tow originated.

Site	Water Body	Date	Time	Depth (m)
Camas	Camas Lake	8/2/2011	1510	0.64
Camas	Camas Lake	8/2/2011	1530	6.10
Camas	Camas Lake	8/2/2011	1545	5.00
Camas	Camas Lake	8/2/2011	1610	7.32
Camas	Camas Lake	8/2/2011	2030	1.77
Camas	Camas Lake	8/2/2011	2045	0.85
Camas	Lake Evangeline	8/3/2011	1240	30.48
Camas	Lake Evangeline	8/3/2011	1310	30.48
Camas	Lake Evangeline	8/3/2011	1320	30.48
Camas	Lake Evangeline	8/3/2011	1500	3.60
Camas	Lake Evangeline	8/3/2011	1522	3.29
Camas	Lake Evangeline	8/3/2011	1130	3.99
Lincoln	Lake Ellen Wilson	8/22/2011	1040	4.27
Lincoln	Lake Ellen Wilson	8/22/2011	1100	4.24
Lincoln	Lake Ellen Wilson	8/22/2011	1115	5.82
Lincoln	Lake Ellen Wilson	8/22/2011	1530	30.48
Lincoln	Lake Ellen Wilson	8/22/2011	1550	30.48
Lincoln	Lake Ellen Wilson	8/22/2011	1620	30.48
Logging	Grace Lake	8/4/2010	1740	5.00
Logging	Grace Lake	8/4/2010	1530	16.00
Logging	Grace Lake	8/4/2010	1600	14.00
Logging	Grace Lake	8/4/2010	1615	6.00
Logging	Grace Lake	8/4/2010	1715	6.00
Logging	Grace Lake	8/4/2010	1720	12.00

APPENDIX I

MICROHABITAT CHARACTERISTICS BY HABITAT UNIT TYPE

Appendix I.1.- Physical habitat characteristics of pools within each study site in Glacier National Park, Montana. Values represent means ± 95% CI of the proportion of total pool habitat comprised of each microhabitat type.

	Site		
Microhabitat	Camas Creek	Lincoln Creek	Logging Creek
Substrate Type			
Sand/silt	0.08±0.05	0.00[1]	0.12±0.05
Small gravel	0.43±0.15	0.20±0.21	0.20±0.05
Large gravel	0.13±0.08	0.08±0.09	0.35±0.06
Cobble	0.10±0.05	0.45±0.17	0.27±0.05
Boulder	0.10±0.05	0.05±0.06	0.06±0.03
Bedrock	0.15±0.12	0.23±0.26	0.00[1]
Cover Type			
Large woody debris	0.03±0.03	0.00[1]	0.58±0.84
Undercut bank	0.00±0.01	0.00[1]	0.08±0.03
Boulder	0.03±0.02	0.00[1]	0.03±0.02
Overhanging vegetation	0.10±0.08	0.00[1]	0.13±0.04
Backwater	0.00[1]	0.00[1]	0.02±0.02

1- No confidence interval calculated as all measured values were zero.

Appendix I.2.- Physical habitat characteristics of glides within each study site in Glacier National Park, Montana. Values represent means ± 95% CI of the proportion of total glide habitat comprised of each microhabitat type.

	Site		
Microhabitat	Camas Creek	Lincoln Creek	Logging Creek
Substrate Type			
Sand/silt	0.12±0.07	0.00[1]	0.23±0.18
Small gravel	0.81±0.08	0.85±0.10	0.25±0.10
Large gravel	0.04±0.04	0.05±0.10	0.21±0.12
Cobble	0.02±0.02	0.10±0.20	0.25±0.14
Boulder	0.01±0.01	0.00[1]	0.07±0.07
Bedrock	0.00[1]	0.00[1]	0.00[1]
Cover Type			
Large woody debris	0.03±0.04	0.00[1]	0.09±0.09
Undercut bank	0.01±0.01	0.00[1]	0.00[1]
Boulder	0.00[1]	0.00[1]	0.03±0.04
Overhanging vegetation	0.07±0.06	0.00[1]	0.12±0.13
Backwater	0.00[1]	0.00[1]	0.15±0.20

1- No confidence interval calculated as all measured values were zero.

Appendix I.3.- Physical habitat characteristics of riffles within each study site in Glacier National Park, Montana. Values represent means ± 95% CI of the proportion of total riffle habitat comprised of each microhabitat type.

	Site		
Microhabitat	Camas Creek	Lincoln Creek	Logging Creek
Substrate Type			
Sand/silt	0.02±0.02	0.00[1]	0.04±0.02
Small gravel	0.42±0.15	0.27±0.18	0.14±0.04
Large gravel	0.20±0.09	0.13±0.13	0.39±0.05
Cobble	0.19±0.09	0.29±0.16	0.33±0.05
Boulder	0.09±0.05	0.19±0.10	0.10±0.04
Bedrock	0.09±0.10	0.13±0.15	0.00±0.00
Cover Type			
Large woody debris	0.05±0.03	0.07±0.11	0.07±0.02
Undercut bank	0.01±0.01	0.00[1]	0.03±0.02
Boulder	0.01±0.01	0.00[1]	0.04±0.02
Overhanging vegetation	0.13±0.07	0.06±0.06	0.21±0.06
Backwater	0.00[1]	0.00[1]	0.01±0.01

1- No confidence interval calculated as all measured values were zero.

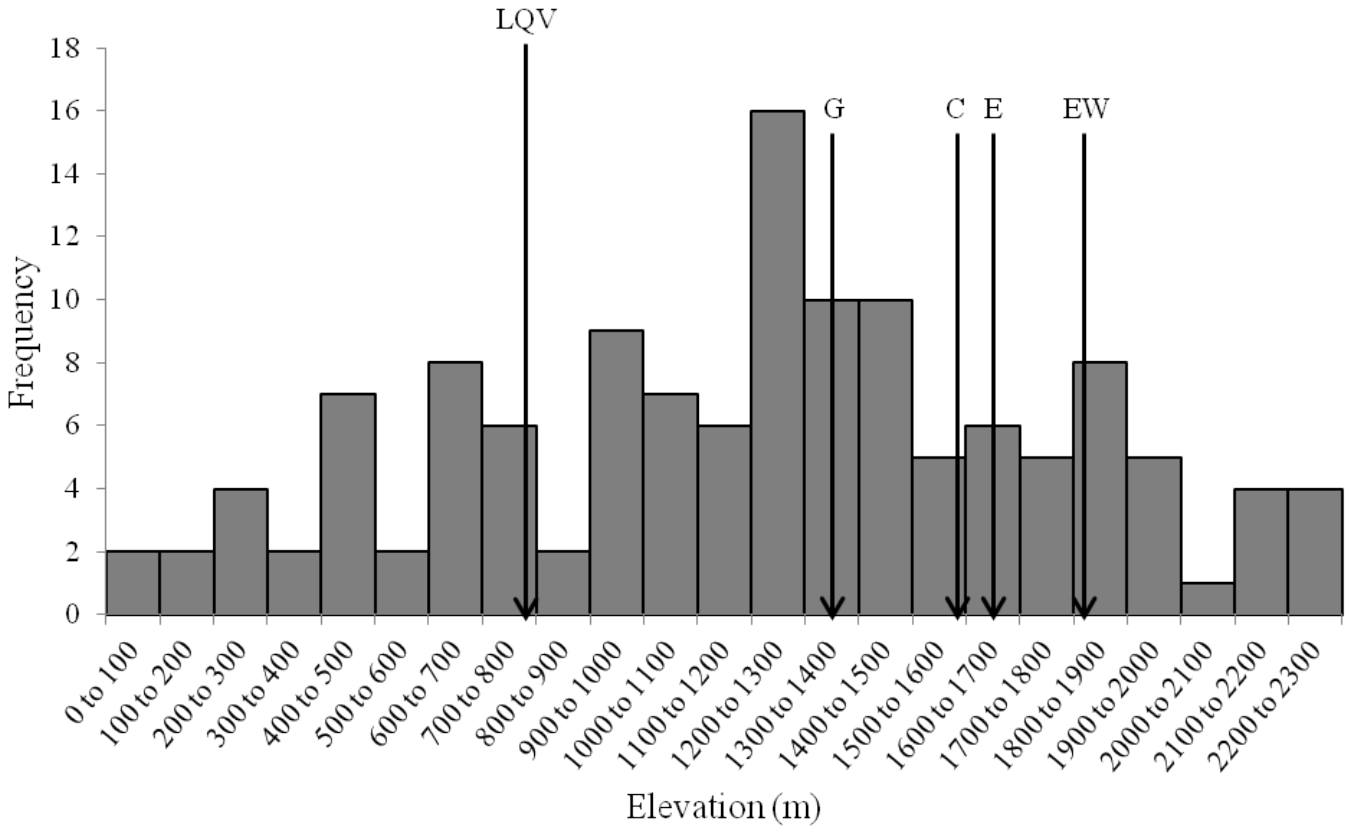
Appendix I.4.- Physical habitat characteristics of cascades within each study site in Glacier National Park, Montana. Values represent means ± 95% CI of the proportion of total cascade habitat comprised of each microhabitat type.

	Site		
Microhabitat	Camas Creek	Lincoln Creek	Logging Creek
Substrate Type			
Sand/silt	0.00[1]	0.00[1]	0.00[2]
Small gravel	0.15±0.13	0.00[1]	0.00[2]
Large gravel	0.15±0.06	0.10±0.12	0.00[2]
Cobble	0.20±0.10	0.20±0.22	0.20[2]
Boulder	0.28±0.10	0.08±0.16	0.80[2]
Bedrock	0.22±0.22	0.62±0.36	0.00[2]
Cover Type			
Large woody debris	0.01±0.02	0.02±0.04	0.00[2]
Undercut bank	0.00[1]	0.00[1]	0.00[2]
Boulder	0.13±0.07	0.00[1]	0.00[2]
Overhanging vegetation	0.11±0.08	0.00[1]	0.00[2]
Backwater	0.00[1]	0.00[1]	0.00[2]

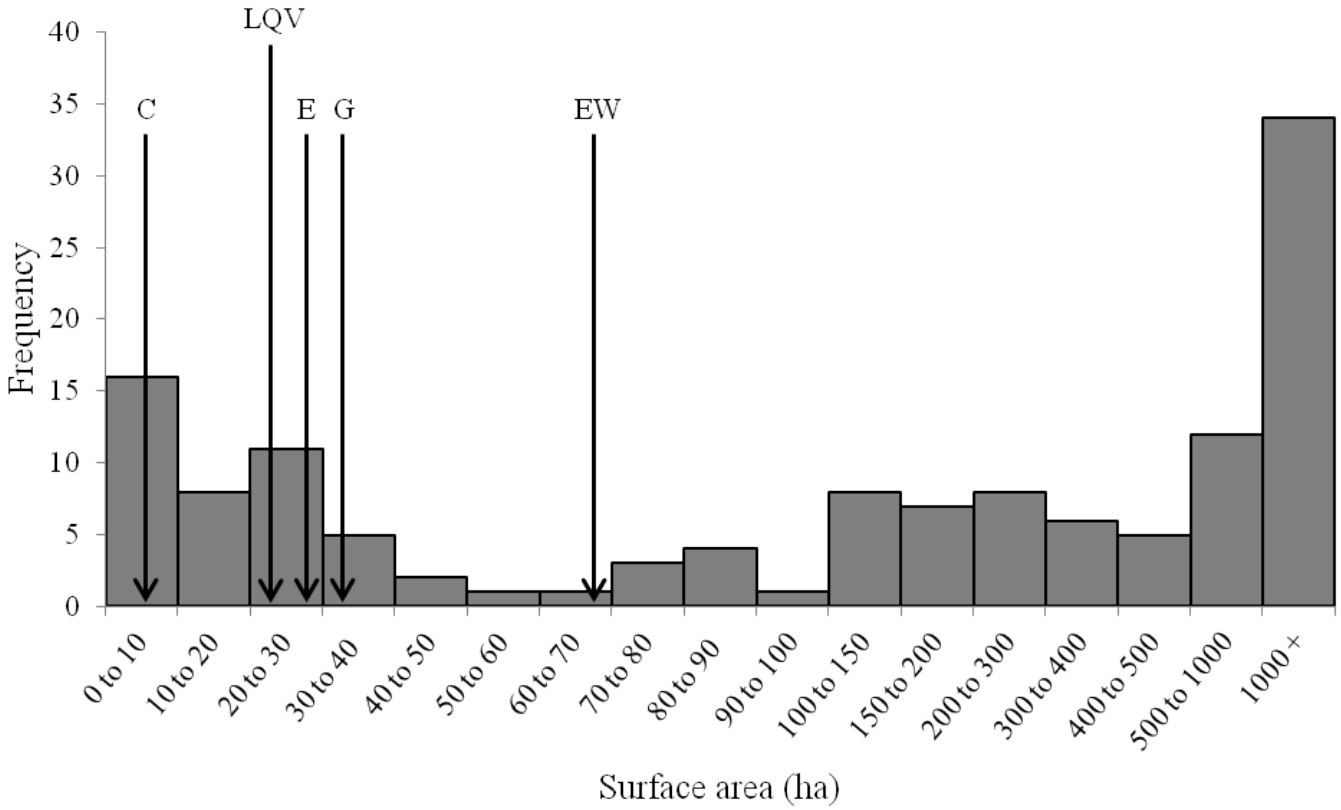
1- No confidence interval calculated as all measured values were zero.
2- Value represents single habitat unit, as only one cascade was present in the Logging study site.

APPENDIX J

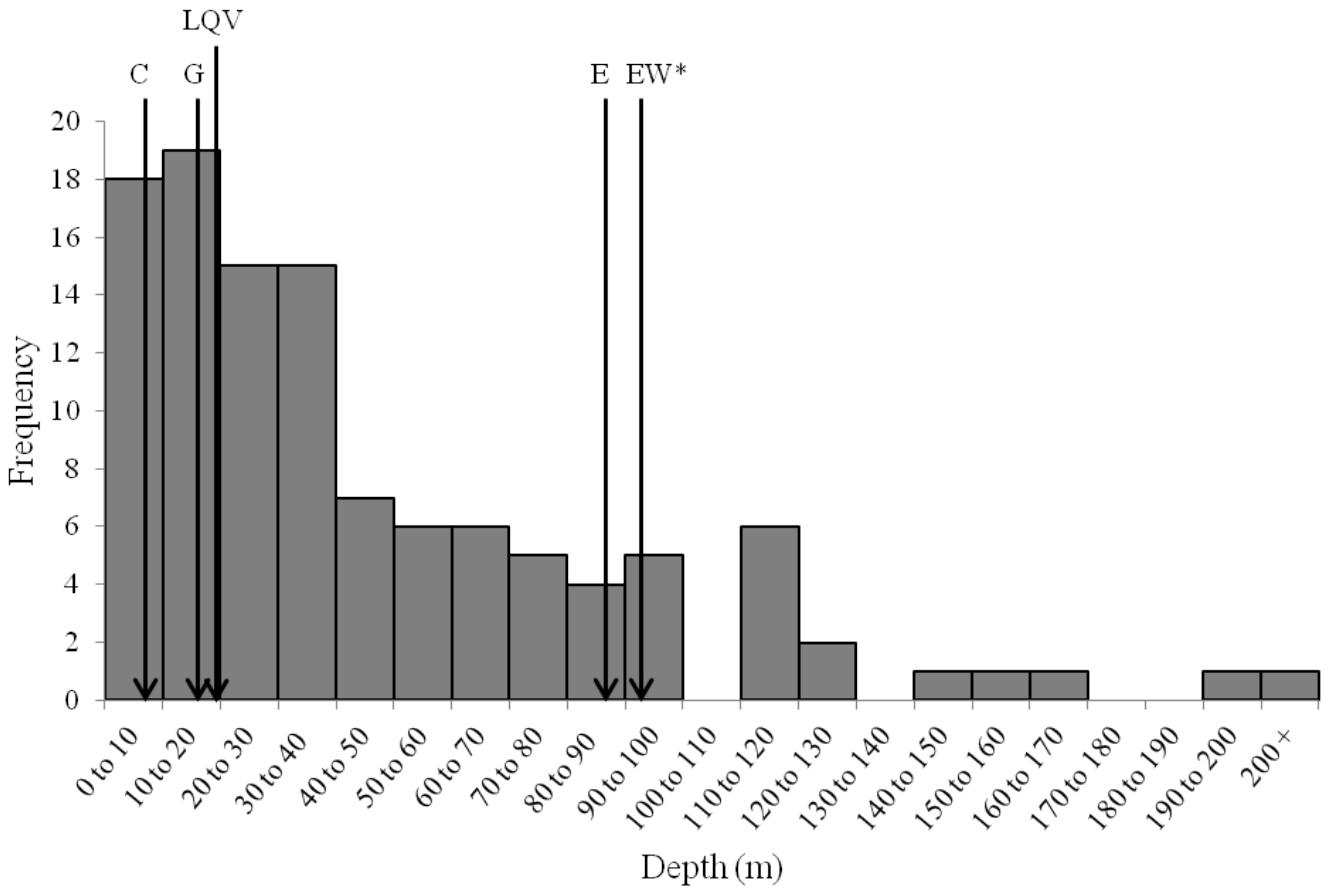
DISTRIBUTION OF PHYSICAL CHARACTERISTICS OF BULL TROUT LAKES IN THE COLUMBIA RIVER DRAINAGE



Appendix J.1.- Elevation of lakes within study sites compared to elevation distribution of lakes containing bull trout within the CRD; C= Camas Lake; G= Grace Lake; E= Lake Evangeline; EW= Lake Ellen Wilson; LQV= Lower quartile value of distribution.



Appendix J.2.- Surface area of lakes within study sites compared to surface area distribution of lakes containing bull trout within the CRD; C= Camas Lake; G= Grace Lake; E= Lake Evangeline; EW= Lake Ellen Wilson; LQV= Lower quartile value of distribution.



Appendix J.3.- Depth of lakes within study sites compared to depth distribution of lakes containing bull trout within the CRD; C= Camas Lake; G= Grace Lake; E= Lake Evangeline; EW= Lake Ellen Wilson; LQV= Lower quartile value of distribution; * = actual depth was not measurable due to equipment limitations.

APPENDIX K

HABITAT CHARACTERISTICS OF LENTIC OFF-CHANNEL MESOHABITATS

Appendix K.- Physical habitat characteristics measured in off-channel lentic mesohabitat in the Camas and Lincoln study sites. Substrate type and cover type are presented as the proportion of the total habitat unit area occupied by each substrate and cover type. Sm Grvl= small gravel, Lg Grvl= large gravel, Cbbl= cobble, Bldr= boulder, Bdrk= bedrock, LWD= large woody debris, UCB= undercut bank, BLD= boulder, OHV= overhanging vegetation.

					Substrate type						Cover type			
Site	Length (m)	Width (m)	Area (m^2)	Depth (m)	Sand/ Silt	Sm Grvl	Lg Grvl	Cbbl	Bldr	Bdrk	LWD	UCB	BLD	OHV
Camas	49.1	23.8	1168.6	1.5	0.7	0.2	0	0	0.1	0	0.2	0	0	0
Camas	120.0	60.0	7200.0	1.4	1	0	0	0	0	0	0	0	0	0
Camas	110.0	12.0	1320.0	0.4	0.8	0.2	0	0	0	0	0	0	0	0
Camas	102.0	9.5	969.0	0.3	1	0	0	0	0	0	0	0	0	0
Lincoln	19.8	33.3	659.3	1.0	0.9	0	0.1	0	0	0	0	0	0	0

APPENDIX L

LITERATURE REFERENCED TO CREATE

CRITERIA THRESHOLDS

Appendix L.- Specific criteria used to evaluate each major component regarding its suitability for bull trout and the literature referenced to develop each criteria.

Major Component	Criteria	Supporting literature
Recipient Habitat	Percent stream comprised of pool habitat units >4%	Fraley and Shepard 1989; Sexauer 1994; Saffel and Scarnecchia 1995; Dambaucher and Jones 1997; Watson and Hillman 1997; Jakober et al. 1998; Tennant 2010
	Coarse substrate (> 75 mm) present	Pratt 1984; Baxter and McPhail 1997; Dambaucher and Jones 1997; Watson and Hillman 1997; Muhlfeld and Marotz 2005
	Gravel substrate (20 – 75 mm) present	Fraley and Shepard 1989; McPhail and Baxter 1996; Dambaucher and Jones 1997; Baxter and McPhail 1997
	Proportion cover in stream habitat > 15%	Pratt 1984; Shepard et al. 1984; Fraley and Shepard 1989; Rieman and McIntyre 1993; Goetz 1994; Dambacher and Jones 1997; Rich et al. 2003; Muhlfeld and Marotz 2005; Tennant 2010
	Mean August stream temperature ≤13°C	Fraley and Shepard 1989; Rieman and McIntyre 1993; Saffel and Scarnecchia 1995; Selong et al. 2001; Isaak et al. 2010; Jones 2012; Jones et al. 2013
	Mean August stream temperature 13-15°C	Fraley and Shepard 1989; Rieman and McIntyre 1993; Saffel and Scarnecchia 1995; Selong et al. 2001; Isaak et al. 2010; Jones 2012; Jones et al. 2013
	Maximum daily stream temperature ≤ 9°C during September/October	McPhail and Murray 1979; Fraley and Shepard 1989; Muhlfeld et al. 2006; Dunham and Gallo 2008; Dunham et al. 2011

Appendix L continued.

Major Component	Criteria	Supporting literature
Recipient Habitat	Mean August lake temperature ≤14°C; maximum lake temperature ≤16°C	Fraley and Shepard 1989; Rieman and McIntyre 1993; Saffel and Scarnecchia 1995; Selong et al. 2001; Dunham and Gallo 2008; Dunham et al. 2011; Jones 2012; Jones et al. 2013
	Mean August lake temperature 14.1-15°C; maximum lake temperature ≤16°C	Fraley and Shepard 1989; Rieman and McIntyre 1993; Saffel and Scarnecchia 1995; Selong et al. 2001; Dunham and Gallo 2008; Dunham et al. 2011; Jones 2012; Jones et al. 2013
	Stream length comparable to neighboring systems supporting bull trout	Meeuwig et al. 2007; Dunham and Gallo 2008; Dunham et al. 2011
	Maximum lake depth > 16 m	Donald and Alger 1993; Wilhelm et al. 1999; Fredenberg 2002; Meeuwig and Guy 2007; Meeuwig et al. 2008; Guy et al. 2011;This study
	Maximum lake depth 2.2 – 16 m	Donald and Alger 1993; Wilhelm et al. 1999; Fredenberg 2002; Meeuwig and Guy 2007; Meeuwig et al. 2008; Guy et al. 2011;This study
	Lake surface area > 25 ha	Donald and Alger 1993; Wilhelm et al. 1999; Fredenberg 2002; Fredenberg 2003; Meeuwig and Guy 2007; Meeuwig et al. 2008; Guy et al. 2011; This study
	Lake surface area 3.4 – 25 ha	Donald and Alger 1993; Wilhelm et al. 1999; Fredenberg 2002; Fredenberg 2003; Meeuwig and Guy 2007; Meeuwig et al. 2008; Guy et al. 2011; This study

Appendix L continued.

Major Component	Criteria	Supporting literature
Recipient community	Hybridizing or competing species detected	Leary et al 1983; Goetz 1989; Markle 1992; Nelson and Paetz 1992; Donald and Alger 1993; McPhail and Taylor 1995; McPhail and Baxter 1996; Watson and Hillmann 1997; Gunckel et al. 2002; Kanda et al. 2002; Fredenberg 2002; Rich et al. 2003; Rieman et al. 2006; McMahon et al. 2007; Guy et al. 2011; D'Angelo and Muhlfeld 2013
	Threatened, endangered, or sensitive native aquatic species detected	Marnell 1997; USFWS endangered species list; Montana Natural Heritage Program species of special concern list
Donor population	*C/f* estimates ≥ 0.2 fish/net hour	Meeuwig and Guy 2007; Meeuwig et al. 2007
	Observed heterozygosity ≥ 0.5	Meeuwig and Guy 2007; DeHaan et al. 2008; DeHaan et al. 2010; DeHaan et al. 2011; Nyce et al. 2013