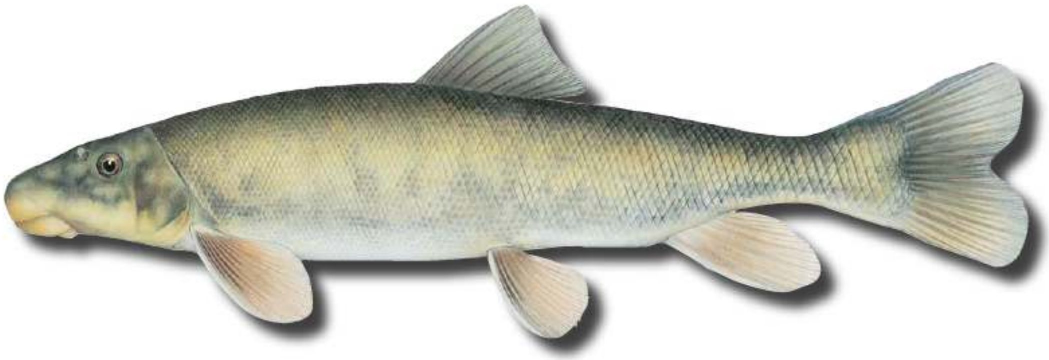
Black Hills National Forest, USDA Forest Service Region 2

Mountain Sucker MIS Monitoring Protocol



Mountain sucker (*Catostomus platyrhynchus*). Illustration by © Joseph Tomelleri

Protocol prepared by:

Daniel C. Dauwalter and Frank J. Rahel
Department of Zoology and Physiology, University of Wyoming, Laramie, WY

Steven R. Hirtzel
Black Hills National Forest, USDA Forest Service, Custer, SD

Kenneth G. Gerow
Department of Statistics, University of Wyoming, Laramie, WY

Gregory D. Hayward
USDA Forest Service, Region 2, Denver, CO

January 2008

List of Preparers

Daniel C. Dauwalter is a Post-doctoral Research Associate, Department of Zoology and Physiology, University of Wyoming, Laramie, Wyoming 82071.

Frank J. Rahel is Professor, Department of Zoology and Physiology, University of Wyoming, Laramie, Wyoming 82071.

Steven R. Hirtzel is a fisheries biologist for the Black Hills National Forest, United States Department of Agriculture, Forest Service, Custer, South Dakota 57730.

Kenneth G. Gerow is Professor, Department of Statistics, University of Wyoming, Laramie, Wyoming 82071.

Greg D. Hayward is Regional Wildlife Ecologist, Rocky Mountain Region – Region 2, U.S. Forest Service, Denver, Colorado

Acknowledgments

Jerry Wilhite of the South Dakota Department of Game, Fish, and Parks and Paul Mavrakis of the Wyoming Game and Fish Department commented on a draft of the protocol.

Table of Contents

List of Tables

List of Figures

Chapter 1. Overview

1.0 Overview and Purpose

The mountain sucker (*Catostomus platyrhynchus*) has been identified as a management indicator species (MIS) for the Black Hills National Forest (USDA Forest Service 2005a). It was selected because it is a native species, it is fairly well distributed across the forest, and its populations should reflect the effects of forest management on stream health and aquatic biota (SAIC 2005). The goals of mountain sucker MIS monitoring are to 1) document trends in mountain sucker populations (abundance and distribution); and 2) monitor changes in aquatic habitat (quality and connectivity). Specifically, this document addresses Forest Plan Objective 238d, which is to maintain or enhance habitat quality and connectivity for the mountain sucker as outlined in specific direction pertaining to monitoring fish, aquatic habitat, and riparian habitat (USDA Forest Service 2005a). This interrelationship is shown conceptually in Figure 1.

1.1 Background and Business Needs

The Black Hills National Forest in South Dakota and Wyoming has selected the mountain sucker as an MIS for the Forest. The distribution of the mountain sucker ranges from California west of the Continental Divide to South Dakota in the east, and from southern Utah to Alberta and Saskatchewan, Canada (Baxter and Stone 1995). The mountain sucker inhabits small creeks, mountain lakes, and some larger rivers. A brief description of mountain sucker biology and ecology is reported in Section 2.1.1, and a detailed description is given by Isaak et al. (2003) and Belica and Nibbelink (2006). Anthropogenic activities that typically affect aquatic ecosystems are considered threats to the viability of mountain sucker populations. Examples of such activities are: habitat degradation and loss (e.g., sedimentation), impoundments, loss of habitat connectivity due to dams and road culverts, hybridization, and introduction of non-native species (Belica and Nibbelink 2006).

The mountain sucker has experienced a decrease in distribution in some parts of U.S. Forest Service Region 2. In the Missouri River Drainage in Wyoming, the mountain sucker was found to occur less frequently than in the 1960's at several spatial scales. There was a decrease in distribution at the stream site, stream, and subdrainage spatial scales (Patton et al. 1998). Land management and irrigation activities that increase turbidity and siltation were thought to be causes for the reduced distribution. On the Black Hills National Forest, the mountain sucker occupies most of its historical distribution (Isaak et al. 2003) though abundance and presence has varied at specific locations. Analysis of population data at a few selected stream sites showed no trends, but these populations exhibit high temporal variation in abundance that can make trend detection difficult (Isaak et al. 2003). Another analysis that included more sites also showed no overall trend among sites, but there were increasing and decreasing trends at some individual sites (Appendix A). Only in Annie Creek, Site 06 did mountain sucker abundance and biomass decrease. At this site, the density of mountain suckers was estimated at 1534 / ha (6.8 kg / ha) in 1995, but from 2001 to 2004 no mountain suckers were collected.

The legal and conservation status of the mountain sucker varies depending on region and listing organization (Belica and Nibbelink 2006). The mountain sucker is not listed as endangered or threatened under the Endangered Species Act by the United States

Fish and Wildlife Service. The mountain sucker is listed as a sensitive species by the Forest Service in Region 2. The Natural Heritage Network has listed the Global Status and United States National Status of the mountain sucker as Secure (G5, N5). Its Wyoming Status is Secure (S5) but its South Dakota status is Vulnerable (S3). The Wyoming Game and Fish Department has designated the mountains sucker as a species of greatest conservation need and assigned it a status of NSS3, indicating that the species is widespread and populations are stable but habitat availability may be vulnerable or declining (WGFD 2005). The State of South Dakota identified the mountain sucker as a species of greatest conservation need and lists the mountain sucker as S3, indicating that it is very rare and local throughout its range, found locally in a restricted range, or vulnerable to extinction throughout its range due to other factors (SDGFP 2006).

1.2 Key Concepts

An aspect of mountain sucker ecology that is important to MIS monitoring is that its distribution on the Black Hills National Forest is patchy. The patchy distribution of mountain sucker populations influenced how sites were selected for abundance monitoring. Sites were selected where mountain sucker have occurred historically. Landownership was also a consideration in site selection. Population abundance can also fluctuate substantially over time which can make the detection of population trends difficult (Appendix A).

1.3 Roles and Responsibilities

The mountain sucker has been selected as a fish MIS for the Black Hills National Forest. Thus, this protocol is the responsibility of the Black Hills National Forest, and its intent is to ensure the implementation of a consistent monitoring program across time. Other forests may use this protocol as guidance to develop monitoring programs for mountain sucker or other fish species. Coordination with the respective State resource agencies is also encouraged.

1.4 Relationship to Other Federal Inventory and Monitoring Programs

This protocol incorporates monitoring methods recommended by other Forest Service technical guides. The Aquatic Ecological Unit Inventory (AEUI) Technical Guide establishes national attributes and their measurement protocols for aquatic ecological units (Potyondy et al. 2006). Fish population and habitat monitoring will be based on guidelines described by the AEUI Technical Guide. The Bureau of Land Management's Monitoring Streambanks and Riparian Vegetation – Multiple Indicators Guide was also used to describe the methods for measuring some aquatic/riparian metrics (Burton et al. 2007). The National Inventory and Assessment Procedure for identifying barriers to aquatic organism passage at road-stream crossings gives guidance for the inventory of road crossings (Clarkin et al. 2005). This document is referenced in regards to monitoring stream connectivity and how to determine whether a crossing is a fish passage barrier.

Fish population and aquatic habitat data collected as part of this protocol will be compatible with information stored in the Forest Service Natural Resource Information

System (NRIS) database. All data collected can be incorporated into NRIS to facilitate data sharing and meet the information needs of managers.

To the maximum extent practical, data will be collected in a manner consistent with ongoing State fish population and habitat monitoring efforts to optimize data sharing and collation.

1.5 Quality Control and Assurance

Quality control and assurance for this protocol was met by employing peer review and the use of established, peer-reviewed methods for monitoring. Personnel at several levels of the Forest Service and independent scientists and statisticians at the University of Wyoming developed and reviewed this protocol. Biologists from the South Dakota Department of Game, Fish, and Parks and the Wyoming Game and Fish Department also reviewed this protocol. Furthermore, methods employed herein are based on published peer-reviewed methods and protocols (e.g., Clarkin et al. 2005; Vesely et al. 2006; Potyondy et al. 2006; Burton et al. 2007).

1.6 Change Management

There may be a need to modify this protocol in the future because it is considered a draft until it has been field tested for at least one season (Vesely et al. 2006). New guidelines for monitoring set by the U.S. Forest Service (or some higher Federal entity) may change monitoring and reporting requirements to better support forest planning. This protocol would then be updated to accommodate changes in monitoring and reporting requirements. Changes should be made by the next monitoring season after new requirements are mandated. However, the data collection protocols recommended herein are well-established and are not expected to change. In contrast, new methods for the analysis of population trends may result in the update of data analysis methods. This protocol should be reviewed after three monitoring periods by Forest Service aquatic and research scientists. Their recommendations may require a revised version of this protocol.

Chapter 2. Specific Inventory and Monitoring Strategies

2.0 Objectives

The objectives of this MIS monitoring protocol are twofold: 1) document trends in mountain sucker populations (abundance and distribution) on the Black Hills National Forest; and 2) monitor changes in stream habitat (quality and connectivity) on the Black Hills National Forest.

Trends in abundance will be monitored on the Black Hills National Forest at sites where mountain sucker have been collected previously; hereafter these sites are referred to as abundance sites. Abundance sites will be located at sites where mountain sucker have been previously collected on National Forest System lands by the South Dakota Department of Game, Fish, and Parks and the Wyoming Game and Fish Department since 1984. Stream reaches where the primary management emphasis is for a non-native recreational fishery were removed from consideration. Examples include Spearfish Creek and the tailwater fisheries below Deerfield, Pactola and Sheridan dams on Castle, Rapid and Spring creeks, respectively. Mountain sucker abundance will be measured at each site every three years, and trends in abundance over time will be estimated.

Monitoring is aimed at detecting a 2.5% annual decline in mountain sucker abundance among all sites after 10 years or longer at a statistical Type I error rate (i.e., falsely concluding that a change has occurred) of $\alpha = 0.20$. A 2.5% annual decline yields a 22% decline after 10 years. A Type I error rate equal to $\alpha = 0.20$ (as opposed to a traditional $\alpha = 0.05$) was selected to increase the chance of detecting real changes in mountain sucker populations. This Type I error rate is also balanced with the Type II error rate of $\beta = 0.20$ (failure to detect changes that are real). This plan was developed, in part, to detect 2.5% annual decline in mountain sucker populations after 10 years with a minimum statistical power $(1 - \beta) = 0.80$. A statistical power of 0.80 balances Type I and Type II error rates at 0.20.

Trends in the distribution of mountain sucker will be monitored at sites located within selected watersheds (hereafter referred to as distribution sites) on the Black Hills National Forest. Distribution sites will be located in 8th level Hydrologic Unit Code watersheds that are randomly selected from a sampling frame of 8th level watersheds (defined below). The same distribution sites within the selected watersheds should be sampled every 5 years, and at least every 10 years, to determine mountain sucker presence. Monitoring is aimed at detecting a significant increase or decrease in the distribution of mountain sucker in all 8th level watersheds that have perennial streams and where >50% of the perennial stream length is adjacent to National Forest System land. Specifically, monitoring is intended to detect an two-fold increase or decrease in the odds of a watershed having mountain sucker present after 10 years at $\alpha = 0.20$. A two-fold increase or decrease in the odds is equivalent to a 1.07 annual increase or decrease in odds.

Aquatic habitat will be monitored at the same sites where mountain sucker abundance is monitored (referred to as abundance sites) on the Black Hills National Forest. Stream habitat will be monitored at abundance sites every three years to determine changes in habitat characteristics. Eight attributes of stream habitat will be monitored: sinuosity, river reach gradient, bankfull width:depth ratio, streambed material size, large woody material, pool habitat, residual pool depth, and streambank stability. The monitoring objective is to have an 80% chance to detect a 2.5% annual increase or decrease in these attributes of aquatic habitat among all sites after 10 years or longer at $\alpha = 0.20$.

Connectivity of aquatic habitat will be monitored by comparing the future addition or removal/improvement of instream barriers in relation to the existing baseline condition. The initial step would be to inventory the current status of barriers in streams and watersheds occupied by the mountain sucker. Road-stream crossings on National Forest System lands would be assessed using the “natural stream simulation” criteria identified in the national protocol (Clarkin et al. 2005). Road-stream crossings on county or state jurisdictional roads may also be inventoried, but private road-stream crossings would not be inventoried. Aerial photography may be used to identify potential barriers, such as small earthern dams, on private lands. Potential natural barriers, such as stream gradient, may be inventoried on a qualitative basis. Fish passage at these natural barriers would be evaluated based on professional judgment given the lack of data on mountain sucker swimming performance (e.g. jumping ability, burst and sustained swimming speeds).

The specific monitoring objective is to maintain or enhance stream connectivity based on whether there is a positive, negative or neutral change in stream connectivity based on the number of barriers removed or improved over time. The number of road crossings improved to facilitate fish passage will be documented. Improvements to other barriers that inhibit the movement of aquatic organisms (e.g., dams) will also be documented for the entire Black Hills National Forest.

2.1 Planning and Design

2.1.1 Species' Life History – The biology and ecology of the mountain sucker has been described by several authors (Hauser 1969; Campbell 1992; Isaak et al. 2003; Belica and Nibbelink 2006). Mountain sucker have been found in streams, large rivers, lakes, and reservoirs (Baxter and Stone 1995). They are most often found in cool, clear mountain streams but at lower elevations than trout (Smith 1966; Isaak et al. 2003). Mountain sucker often associate with the stream bottom and cover near the transition areas of runs and pools (Decker 1989).

Like most catostomids, mountain sucker are benthic feeders. They consume mostly algae and some small invertebrates (Baxter and Stone 1995). Inorganic material is also ingested, presumably during benthic feeding (Hauser 1969).

Mountain sucker reproduction occurs during spring, but the exact timing of reproduction varies among populations throughout its range. Mountain sucker spawn in June and early July in Montana when water temperatures are between 17 and 19°C (Hauser 1969). They spawn in mid-August in California (Decker 1989), and in late-May to late-June in Utah with peak spawning at water temperatures of 9 to 11°C (Wydoski and Wydoski 2002). Mountain sucker spawn in riffles (Hauser 1969), and lentic populations migrate into streams to spawn (Decker and Erman 1992; Wydoski and Wydoski 2002). They become sexually mature at ages two to four (Smith 1966; Wydoski and Wydoski 2002).

The community ecology of mountain sucker is poorly understood. There is often information on co-occurring fish species, dependent on the local fauna, within the wide distribution of mountain sucker. Divergence in gill-raker counts between other species of suckers sympatric with the mountain sucker has been documented and is assumed to result from competition (Dunham et al. 1979). Predator-prey relationships have not been studied, although an inverse relationship between mountain sucker abundance and brown trout (*Salmo trutta*) abundance has been reported (Decker and Erman 1992). Interaction with non-native fish species may also have reduced the abundance and distribution of mountain suckers over time in the Black Hills (USDA Forest Service 2007).

2.1.2 Selected Measures of Population and Habitat – Four measures of mountain sucker populations and stream habitat will be monitored to meet the MIS monitoring objectives of the Black Hills National Forest. Trends in mountain sucker abundance will be monitored using the metric: *mean percent annual change in mountain sucker density*. Trends in the distribution of mountain sucker will be monitored using the metric: *annual change in the odds of a watershed having mountain sucker present*. Trends in aquatic habitat will be monitored using the metric: *mean percent annual change in habitat attribute X*. Several characteristics of aquatic habitat will be measured and monitored at each site, and percent annual change in each attribute will be monitored. Trends in the connectivity of stream habitats will be monitored using the metric: *cumulative number of barriers to fish movement improved*.

2.1.3 Sampling Design – Sampling designs will be implemented for MIS monitoring that allow trends in mountain sucker populations and aquatic habitat to be extrapolated to areas beyond the sites and watersheds where monitoring will occur. There are certain technical terms that are used to define a sampling design, and definitions of these terms are given by Thompson et al. (1998):

Element: an item on which some type of measurement is made or some type of information is recorded. An element might be a fish, a stream reach, or a watershed.

Target population: all elements of interest within some defined area and time period on which information is wanted. A target population might be all fish in streams or all watersheds within an explicitly defined geographic area from time A to time B.

Sampling unit: a unique set usually of one or more elements, although in area sampling a sampling unit may not contain any elements. A sampling unit might be a stream reach or a watershed. For some sampling designs an element and sampling unit are equivalent.

Sampling frame: a complete list of the sampling units within the defined geographic area of the target population that is available for sampling. A sampling frame might be all stream reaches or watersheds within a state boundary or the boundary of a National Forest.

Sampled population: all elements associated with sampling units listed within the sampling frame. The sampled population should coincide with the target population but may not due to feasibility and convenience. The applicability of conclusions made regarding the sampled population to the target population depends on the degree of their coincidence. A sampled population might be all fish in stream reaches or watersheds within an explicitly defined geographic area.

Sample: a group of sampling units selected during a survey. A sample might be a subset of stream reaches or watersheds selected from the sampling frame.

Monitoring requires sampling to make inferences regarding an entire target population. That is, information collected from a sample of sites is extended to all sampling units (sites) in the sampling frame and to the sampled population. Thus, it is essential that all components of a monitoring program be defined. Each design component is defined differently for each mountain sucker population and aquatic habitat metric being monitored (Table 1), but all of them correspond to the monitoring objectives of this protocol.

Trends in the abundance of mountain sucker on the Black Hills National Forest will be monitored at streams sites where mountain sucker have occurred since 1984. The *target population* is all stream sites with mountain sucker populations. The South Dakota Department of Game, Fish, and Parks has sampled stream fishes at 440 sites on the Black Hills National Forest from 1984 to 2004. Mountain sucker were collected at 97 of the

440 sites. The Wyoming Game and Fish Department has also collected mountain suckers on the Black Hills National Forest in Wyoming. Mountain sucker were collected at 2 of 8 stream sites sampled on the Bearlodge District of the Forest; however, additional inventory sampling would be helpful to determine the status of mountain sucker on the Bearlodge District. All sites where mountain sucker have been collected were considered candidates for MIS monitoring and represented the *sampling frame*, and each candidate site represented both the *sampling unit* and *element*. Therefore, the *sampled population* is all sites where mountain sucker have been collected since 1984. A *sample* of 26 of these sites was selected for MIS monitoring based on the proximity of each site to other sites, whether the site was on or adjacent to Forest land (as opposed to private land), and to ensure that major drainages with perennial streamflow on the Forest were represented (Figure 4, Table 2). Selected stream reaches managed for recreational trout fisheries were also excluded. These reaches include Spearfish Creek and the tailwater reaches of Castle, Rapid and Spring creeks downstream of Deerfield, Pactola and Sheridan dams, respectively. The South Dakota Department of Game, Fish, and Parks samples these reaches with greater frequency to monitor trout populations. Fish population data from these sites should be available for analysis either independent of or in combination with the mountain sucker abundance data. The measurement on each element and sampling unit (i.e., abundance site) in the sample is the percent annual change in mountain sucker density. The monitoring metric is the average of trends across sites, or more specifically the *mean percent annual change in mountain sucker density*. Although the historical distribution of the mountain sucker extends across the Forest, the distribution is patchy and not known for many localized areas on the Forest. This patchy distribution precluded

using an unbiased site-selection process for abundance monitoring (e.g., random or systematic) because it could have resulted in many sites being selected where mountain sucker do not occur. Monitoring trends in mountain sucker abundance where mountain sucker do not occur would have resulted in an inefficient monitoring effort. Because the sampled population differs from the target population, care must be taken when making inferences regarding percent change in mountain sucker density to the target population (Cochran 1977). Additional information is needed regarding the similarity between sites in the sampling frame and all potential stream sites on the Black Hills National Forest.

Trends in the distribution of mountain sucker on the Black Hills National Forest will be monitored by determining their presence in watersheds over time. The *target population*, *sampled population* and *sampling frame* for distribution monitoring is all 8th level watersheds on the Black Hills National Forest that have perennial streams and that have >50% of perennial stream on National Forest System land. The target population, sampled population, and sampling frame are equivalent for this design. Of the 879 8th level watersheds on the Black Hills National Forest, 184 were included in the sampling frame for distribution monitoring (Figure 5). A *sample* of 30 watersheds was randomly selected from the sampling frame (Figure 6, Table 3); watersheds are both the *sampling unit* and *element* in this design. The measurement on each sampling unit and element (i.e., watershed) is the presence of mountain sucker at a site. A stream site within each watershed will be identified to determine the presence of mountain sucker as frequently as every 5 years and at least every 10 years; the same sites within each watershed will be monitored each time period. The proportion of watersheds with mountain sucker present will be determined for each monitoring time period, and the metric *annual change in the odds of a watershed having mountain sucker present* will be estimated.

Characteristics of aquatic habitat will be monitored at the same stream sites where mountain sucker abundance will be monitored. Therefore, the design components are defined exactly the same way as they are for monitoring trends in mountain sucker abundance as described above. Aquatic habitat will be measured at each selected site, the percent annual change in habitat attribute X will be estimated for each site, and the metric *mean percent annual change in habitat attribute X* (for each attribute) will be estimated across all abundance sites. Multiple aquatic habitat attributes will be measured per site (described in Section 2.2.1 Data Collection Methods), and trends among sites per attribute will be estimated and monitored. Most habitat attributes are expected to change by some percentage each year and is why the monitoring metric is percent annual change (Larsen et al. 2004). However, if it is expected that an attribute will change by a constant amount per year, then the monitoring metric should be: *annual change in habitat attribute X*.

Connectivity of aquatic habitat will be inventoried forest-wide on the Black Hills National Forest. Many of the design components for monitoring connectivity have the same definition because improvement to any instream structure on the Forest should be known and documented. Thus, there is no need to make inferences from a sample to the target population of all barriers on the Forest. The *target population, sampled population,* and *sampling frame* for monitoring connectivity are all equivalent. They are defined as all movement barriers on the Forest. There is not a *sample* because all *sampling units* and *elements* (i.e., barriers) in the sampling frame will be monitored. The improvement of structures that inhibit the movement of aquatic organisms will be documented to monitor the metric *cumulative number of barriers to fish movement improved*.

Sampling schedule – The protocol for monitoring mountain sucker populations and aquatic habitat monitoring on the Black Hills National Forest is based on an "always revisit" design. Abundance sites will be revisited every three years to monitor mountain sucker abundance and aquatic habitat, and all 26 abundance sites will be sampled during the same year. Distribution sites within selected watersheds should be revisited every five years and at least every 10 years, and all sites will be sampled during the same year. Revisiting the same sites during each monitoring period results in the highest probability of detecting changes in mountain sucker abundance and distribution and aquatic habitat over time (Urquhart and Kincaid 1999). The field sampling timeframe for monitoring both abundance and distribution sites will be during the summer-fall seasons from June 1 to October 1.

2.1.4 Existing Data and Pilot Studies – Fish collection data exist for Black Hills National Forest streams from several time periods. Early information on fish distributions on the Black Hills was collected during the late 1800's (Evermann 1893; Evermann and Cox 1896). Another survey of Black Hills streams was conducted in the 1960's (Stewart and Thilenius 1964). A systematic survey of major Black Hills streams was done in the 1980's (Ford 1988). The Wyoming Game and Fish Department has sampled some Black Hills streams in Wyoming as early as the 1960s. More recent data from 1988 to 2004 are present in a variety of reports (e.g., Meester 1993). This last dataset is available from the South Dakota Department of Game, Fish, and Parks in their fisheries database. These most recent data were used to summarize variability in population abundance of mountain sucker, determine major sources of variation in population abundance, conduct population trend analysis, estimate mountain sucker capture probabilities, and model the distribution of mountain sucker on the Black Hills National Forest (Appendices A, B, C).

2.1.5 Prospective Power Analysis – A prospective power analysis was conducted to evaluate the ability of this protocol to detect trends in mountain sucker population abundance (Appendix A). This analysis showed that a 2.5% annual decline in mountain sucker densities could be detected within 10 years with a statistical power $(1 - \beta) = 0.80$ at $\alpha = 0.20$.

Other researchers have used data collected for monitoring programs to estimate the statistical power to detect changes in stream habitat over time. Larsen et al. (2004) used stream habitat data from the Pacific Northwest to estimate the power to detect changes in habitat characteristics important to salmonids. Using a sampling design that specified annual revisits to a network of 30 sites, they determined that changes of 2% per year in canopy cover, residual pool depth, fine sediments, and volumetric density of large wood could be detected within 9, 13, 14, and 17 years, respectively, with power = 0.80 and $\alpha = 0.05$. If managers are willing to accept a higher Type I error rate, i.e., risking saying habitat is changing when in fact it is not, these small changes could be detected even sooner at the same level of statistical power.

2.1.6 Modeling Mountain Sucker Distribution – Existing GIS data and logistic regression were used to determine how physical stream characteristics and brown trout densities affected the occurrence of mountain sucker at stream sites on the Black Hills National Forest (Appendix C). Stream permanence, stream order, stream slope, and elevation interacted in complex ways to influence the distribution of mountain sucker. Mountain sucker were more likely to occur in perennial versus non-perennial streams. They were also more likely to occur in large, higher gradient streams at higher elevations, and smaller, low gradient streams at lower elevations. When the logistic regression model was used to predict the probability of mountain sucker presence for all stream segments on the Forest, most stream segments had very low probabilities of occurrence. Only 2% of the total stream length on the Forest had a probability of 0.5 or higher of having mountain sucker present. The density of large brown trout (>20-cm TL) had a negative effect on the presence of mountain sucker. The spatially explicit model predictions can be used to determine where to establish sampling sites within watersheds that are selected for mountain sucker distribution monitoring.

2.2 Data Collection

2.2.1 Data Collection Methods – Mountain sucker populations and aquatic habitat will be monitored at selected stream sites on the Forest. Some sites for abundance monitoring have already been established by South Dakota Department of Game, Fish, and Parks. Other sites for abundance, distribution, and aquatic habitat monitoring will have to be established. The downstream and upstream extent of each reach will be monumented using an appropriate field method (e.g., rebar, benchmark, flagging, paint) and photodocumented to facilitate relocation during future revisits. Establishing a benchmark is the most accurate way to monument a site, and methods for establishing a benchmark are given by Harrelson et al. (1994). Geographic coordinates for the downstream extent of each reach will also be recorded in Universal Transverse Mercator (UTM), Zone 13 coordinates using a global positioning system (GPS) receiver. Recording the location multiple times and averaging location estimates is recommended if a recreational-grade GPS receiver is used (e.g., Garmin, Magellan). Reach coordinates can be entered into a GPS receiver, and then used to navigate directly to the downstream boundary of the reach during revisits. Precisely relocating each reach during revisits is important to reduce sampling variance and improve trend detection (Roper et al. 2003).

Abundance monitoring

Abundance monitoring will take place at 26 stream sites historically sampled by South Dakota Department of Game, Fish and Parks or Wyoming Game and Fish Department where mountain sucker have been collected since 1984 (Table 2). Each site will consist of a 100-m stream reach. Within each, mountain sucker will be sampled using multiple-pass, backpack electrofishing. There are two important things to consider when determining the number of electrofishing passes needed. One is based on the precision of the mountain sucker abundance estimate. The precision of the estimate is determined by the abundance itself, capture probability, and the number of electrofishing passes (VanDeventer and Platts 1989). In general, to maintain adequate precision, 3 electrofishing passes are recommended if capture probability is 0.60 or greater, 4 passes are recommended if capture probability is between 0.45 and 0.60, and 5 passes are recommended if capture probability is between 0.35 and 0.45 (VanDeventer and Platts 1989); these guidelines are based on low abundance and, thus, are conservative. After two electrofishing passes are conducted, capture probability can be estimated in the field as: $\hat{p} = ([C_1 - C_2] / C_1)$, where C_1 is the number of fish caught during pass 1, and C_2 is the number of fish caught during pass 2. This field estimate of capture probability can then be used to determine the number of electrofishing passes needed; however, capture probabilities when sampling mountain sucker in small streams are typically high and only three passes will typically be needed to precisely estimate abundance (Appendix B). Another thing to consider is that capture probability may vary substantially among passes. If this is observed, then four or more passes should be conducted (Riley and Fausch 1992). For example, fish capture probabilities are often higher during pass 1 than during subsequent passes (Riley and Fausch 1992; Peterson et al. 2004; Dauwalter and Fisher 2007).

Suckers from each electrofishing pass will be anesthetized, measured for total length (±1 mm), and weighed (±1 g). If no mountain sucker are collected within the 100-m reach after the first pass, the reach may be extended to a length up to 20 times the channel width and electrofished with one pass to determine if they are present in the vicinity (Potyondy et al. 2006). If no mountain suckers are collected within a reach 20 times the channel width in length for two consecutive monitoring cycles, the remaining stream within the 8th level Hydrologic Unit Code watershed may be systematically sampled to determine mountain sucker presence in the watershed. If no mountains suckers are collected for three consecutive sampling periods, streams within adjacent upstream and downstream 8th level watersheds may be systematically sampled to determine the local distribution of mountain sucker occurrence in surrounding watersheds. Data collected during this extended sampling will be ancillary and will not be incorporated into the formal analyses of trends in abundance and distribution that are described in Section 2.4.1.

Distribution monitoring

The distribution of mountain sucker will be monitored at sites located in 30 selected 8th level Hydrologic Unit Code watersheds (Table 3). A site within each watershed will be identified and sampled to determine mountain sucker presence. It is recommended that sites be located on the stream segments that have the highest probability of having mountain sucker present as predicted by a distribution model developed for mountain sucker on the Black Hills National Forest (Appendix C). To determine mountain sucker presence, a reach length of up to the maximum of 100-m or 20 times the mean channel width, whichever is greater, should be sampled using one pass with a backpack electrofisher (Potyondy et al. 2006: 61). Terminate sampling after one mountain sucker is collected and the presence of mountain sucker has been documented. The same site in each watershed should be sampled during each time period when distribution sampling occurs.

Aquatic habitat monitoring

Several attributes of aquatic habitat will be monitored at the same sites where mountain sucker abundance will be monitored. Sinuosity, river reach gradient, bankfull characteristics, streambed material size, large woody material, pool habitat, and residual pool depth have been identified as attributes of national significance in the Aquatic Ecological Unit Inventory Technical Guide (AEUI; Potyondy et al. 2006), and are considered important characteristics of aquatic habitat in streams on the Black Hills National Forest. Streambank stability is also an important component of aquatic habitat, and will be measured and monitored according to the Monitoring Stream Channels and Riparian Vegetation—Multiple Indicators guide (Burton et al. 2007). All of these attributes of aquatic habitat will be monitored at each abundance site. Measurement of these attributes will follow the guidelines provided by the AEUI Guide (Potyondy et al. 2006) or the Monitoring Stream Channels and Riparian Vegetation—Multiple Indicators guide (Burton et al. 2007). It is recommended that reach lengths be 20 to 30 times the mean channel width for measurement and monitoring of aquatic habitat (Potyondy et al. 2006). This reach will begin at the same downstream location as the 100-m reach used for mountain sucker abundance monitoring. Since many streams on the forest have channels that are 5-m or less in width, habitat measurements should be made within the 100-m reach where mountain sucker sampling occurred. However, in wide streams (≥6-m channel width) the length of stream reach in which habitat should be measured may extend beyond 100-m. In these streams it should be noted that mountain sucker sampling and aquatic habitat sampling occurred on reaches that differed in length. What follows is a brief description of each habitat attribute that will be monitored. However, the appropriate technical guide should be consulted to determine exactly how each attribute should be measured.

Sinuosity reflects channel slope and streambank resistance to erosion (Knighton 1998). Sinuosity of a river reach is evaluated as the stream length divided by valley length. The AEUI guide suggests that sinuosity be measured using maps over two meander wavelengths. However, change in sinuosity can only be monitored if maps are routinely updated and made available. Thus, sinuosity should be measured in the field as the stream length divided by the straight line distance between upper and lower reach boundaries; a reach length of 20 to 30 mean channel widths will typically encompass two meander wavelengths. These measurements can be made using tape measures or with spatial data collected using a GPS receiver (Dauwalter et al. 2006; Dauwalter et al. 2007).

River reach gradient is an indicator of stream energy that predicts channel bedform and channel unit patterns (Potyondy et al. 2006). River reach gradient is measured as the difference in water surface elevation between the upper and lower reach boundaries divided by thalweg length, and reflects the slope of the water surface averaged over the reach length. The difference in elevation can be measured using a hand level, surveyor's level, transit, or total station. It is recommended that river reach gradient be measured using the same bedform at the beginning and end of the reach. For example, elevation should be measured at the head of a riffle at both the downstream and upstream boundaries of the reach.

Bankfull characteristics to be monitored are: bankfull width, mean bankfull depth, and width:depth ratio. These attributes are used to infer stream channel condition and function (Rosgen 1996). Bankfull width and mean bankfull depth are measured at channel cross-sections placed along four consecutive riffles. Measurements are keyed to bankfull stage. Bankfull stage is defined as the elevation of the active floodplain, often a flat depositional surface adjacent to the stream channel. Bankfull stage can also be identified by using visual indicators such as the tops of mature point bars, breaks in slope from horizontal to vertical, changes in bank material, and changes in bank vegetation. Guidance for bankfull identification is provided by several other sources (Harrelson et al. 1994; Rosgen 1996; USDA Forest Service 2005b). Cross-section transects are placed perpendicular to the channel. Channel depths are measured at 20 or more equally spaced locations along each transect. Mean channel depth is calculated as channel cross-section area divided by channel width; this is a more accurate measure of mean channel depth than averaging the measured channel depths. Channel cross-section area can be measured using specialized software programs (Potyondy et al. 2006). If possible, the exact location of each transect should be monumented so that it can be located precisely during site revisits. Relocating exact transect locations improves the detection of trends in bankfull characteristics over time (Roper et al. 2003). Benchmarks are often used as an initial reference point for a stream survey, and are often established near monumented transects. Harrelson et al. (1994) describe how to establish a benchmark for a stream survey.

Streambed material size influences the formation and maintenance of channel morphology, and can indicate the suitability of habitat used by aquatic organisms (Potyondy and Hardy 1994; Potyondy et al. 2006). Streambed material size is measured using the Wolman Pebble Count (Wolman 1954). Pebble count sampling will occur in the first four riffles in the reach. A minimum of 25 particles will be measured in each riffle using the step-toe method. Particles will only be selected from the stream bottom, not from the streambanks. The intermediate axis of each selected particle should be measured. A gravel template can be used to place particles less than 180-mm into a Phi size class. Determine the median diameter of particles within the reach.

Large woody material is an important attribute of streams that influences channel morphology and the abundance and distribution of aquatic biota. The AEUI guide states that size classes for inventorying wood are to be developed by region because the size of important wood pieces may differ depending on stream size and climate. If no size classes have been identified for the Black Hills National Forest, the AEIU guide recommends that the classification system developed by the U.S Environmental Protection Agency's Environmental Monitoring and Assessment Program be used (Potyondy et al. 2006). It identifies a minimum diameter of 10-cm, and has four classifications: 10-cm to less than 30-cm; 30-cm to less than 60-cm; 60-cm to less than 80-cm; 80-cm or greater. The classification system also identifies three length classes: 1.5-m to less than 5-m; 5-m to less than 15-m; and 15-m or larger (Potyondy et al. 2006). This scheme can be used until a size classification system for wood in streams is developed for the Rocky Mountain Region or the Black Hills National Forest.

Pool habitat is an attribute of streams important to many aquatic organisms. The percent of river reach as pool habitat is the attribute of interest. Pool habitats identified by the AEUI guide have the following characteristics: bounded by a head crest (upstream break in slope) and a tail crest (downstream break in slope); concave in profile; occupy greater than half of the wetted channel width; maximum pool depth is 1.5 times the pool-tail depth; pool length is greater than its width. The length of each pool is measured along the thalweg between the head crest and tail crest. The percent of pool habitat is found by adding the total length of all pools and dividing by river reach length (multiplied by 100).

Residual pool depth will also be measured for MIS monitoring because it represents an important characteristics of aquatic habitats (Potyondy et al. 2006). Residual pool depth represents the depth of a pool if water was not flowing over the tail crest and this metric is invariant to streamflow. Residual pool depth is measured as the maximum pool depth minus the depth of the tail crest. Reach-wide residual pool depth is estimated by adding the residual pool depth of all pools in the reach and then dividing by the number of pools.

Streambank stability represents impacts to streambanks from livestock and other sources that can be detrimental to stream habitats used by aquatic organisms. Streambank stability will be estimated at transect locations using a Modified Daubenmire Monitoring Plot Frame (see Appendix D in Burton et al. 2007). Stability will be classified for each frame plot using one of six classifications: CS-covered and stable (non-erosional); CU-covered and unstable (vulnerable); US-uncovered and stable (vulnerable); UU-uncovered and unstable (erosional and depositional); FB-false bank (stable); and UN-unclassified. Detailed description of measurement and classifications are given by Burton et al. (2007). The percent of streambank that is stable (classified as CS or US) is the metric that will be monitored. Streambank stability can be precisely measured, but there are often differences among observers categorizing streambank stability (Archer et al. 2004). Thus, personnel categorizing streambank stability throughout the length of the monitoring period should be trained to reduce this source of variability.

Monitoring barrier removal

Stream connectivity on the Black Hills National Forest can be monitored by documenting the number of barriers to fish movement that are removed, and then assuming that stream connectivity is restored once a barrier is removed. Engineers of the Black Hills National Forest improve road crossings to allow streams to naturally transport water, sediment, and wood. If a road crossing improvement project was conducted, it must be determined beforehand if the crossing is likely to be a barrier to fish movement based on criteria described in Clarkin et al. (2005). Additionally, the removal of dams or the installation of fish passage structures on dams can also restore stream connectivity, but it must be determined what structures were barriers beforehand and if the new structure permits fish movement based on criteria described in Clarkin et al. (2005). The number of these types of improvements to stream habitat connectivity can be documented over time, and will require that fishery biologists communicate with engineers that undertake projects to improve stream connectivity.

Quantifying stream connectivity

Changes in connectivity of the stream network can also be quantified over time. Connectivity can be measured as the mean (or other appropriate measure) length of stream on the forest uninterrupted by barriers. Stream connectivity could be quantified using a geographic information system (GIS) if the spatial location of all streams and barriers are known; this would require the expertise of a GIS specialist. Connectivity could be measured at the forest scale, or within individual watersheds (e.g., 6th level HUC watersheds) where mountain sucker are known to occur. At present, there is a digital coverage of the stream network for the forest, but there is not a comprehensive dataset on road crossings that are barriers to fish movement. The locations of road crossings that are barriers to fish movement have only been determined for specific project level analyses (e.g., proposed timber sales).

In order to quantify changes in stream connectivity over time, an inventory of road crossings that are barriers to fish movement needs to be completed. The National Inventory and Assessment Procedure provides guidance for the inventory of road crossings, and how to determine whether a crossing is a movement barrier (Clarkin et al. 2005). An inventory of road crossings should be conducted to determine which crossings act as barriers and disrupt stream connectivity. Ideally, a forest-wide inventory of potential barriers would be conducted; however, time and fiscal constraints may prohibit an inventory at this scale. Smaller scale inventories could be conducted in watersheds (5th or 6th level watersheds) where the mountain sucker is known to occur.

Once an inventory of barriers has been conducted, changes in stream connectivity can be monitored and barriers can be prioritized for removal. Changes in stream connectivity over time can be quantified as road crossings are modified and barriers are removed. Connectivity could be monitored by quantifying the average length of connected stream segments. Barriers can also be prioritized for removal or modification to facilitate movement of organisms (Clarkin et al. 2005). For example, the barriers that reconnect large areas of aquatic habitat should be given priority for removal.

2.2.2 Personnel Qualifications and Training – Certain qualifications are needed by personnel sampling mountain sucker for MIS monitoring. Scientific collection permits are required by the South Dakota Department of Game, Fish, and Parks and the Wyoming

Game and Fish Department. The Wyoming Game and Fish Department requires that at least one person on each sampling crew be certified in electrofishing by the U.S. Fish and Wildlife Service in order to obtain a scientific collection permit. Uncertified crew members are required to complete on-the-job training by a certified crew member.

Sampling crews should be trained in the fish sampling techniques and habitat assessment protocols used in MIS monitoring. Training can reduce sampling variance attributable to different crews and crew members (Archer et al. 2004). Reduced sampling variance can increase the detection of trends in fish populations and aquatic habitat (Larsen et al. 2004).

2.2.3 Quality Control and Assurance – Quality control and assurance will be done by implementing published methods and crew training. All sampling methods used for monitoring mountain sucker populations and aquatic habitat have been peer-reviewed and are considered useful for meeting monitoring objectives. Crew training will also decrease the sampling and measurement error within and among crews as discussed above. Standardized data sheets will be used in the field to ensure consistency in data collection among monitoring sites. Field data should be reviewed and entered on a weekly basis at a minimum. More frequent reviews, even daily, may be desired at the start of the field season to calibrate field crews and to detect any discrepancies as early as possible. Data will be stored in National databases to ensure data consistency and availability.

2.2.4 Data Forms – Standardized datasheets will be used to collect fish population and aquatic habitat data for MIS sampling. Separate datasheets will be used to record information on mountain sucker abundance at abundance sites, mountain sucker presence at distribution sites within watersheds, and aquatic habitat measured at abundance sites. Fish population monitoring datasheets currently in use by the South Dakota Department of Game, Fish, and Parks or the Wyoming Game and Fish Department will be used to facilitate the collation of this data into each respective State database. Data on improvements to stream connectivity will be documented after communicating with the Engineering Staff of the Black Hills National Forest. Data sheets exist or need to be developed for each of the following monitoring components:

- Abundance monitoring (Appendix D)
- Distribution monitoring (to be developed)
- Habitat monitoring (to be developed)
- Barrier removal and connectivity (to be developed)

2.2.5 Logistics – An annual operation plan should be developed for each monitoring year. Operation plans should include information regarding the status of memorandum's of understanding, the status of permits for land access (if needed) and scientific collection permits, plans for field equipment and vehicles, a checklist of field equipment, and safety considerations (Vesely et al. 2006). Scientific collection permits will need to be obtained from the South Dakota Department of Game, Fish, and Parks and the Wyoming Game and Fish Department.

2.3 Data Storage

All data collected as part of the monitoring plan for the Black Hills National Forest will be stored in hardcopy and electronic form and maintained by the biologist that is leading MIS monitoring. Data collected in the field will be reviewed for completeness and errors. Aquatic habitat and geographic information system (GIS) data will be stored in the aquatic habitat and GIS sections of the Natural Resource Information System (NRIS)-WATER, respectively (Vesely et al. 2006; Potyondy et al. 2006). Mountain sucker data will be entered into the aquatic biota section of NRIS-WATER. Data collected for MIS monitoring may not be compatible with current NRIS capabilities, and developers of NRIS may need to be contacted to enhance the system to store certain types of data. Data will also be submitted to South Dakota Department of Game, Fish, and Parks and Wyoming Game and Fish Department to comply with scientific collection permit requirements.

2.4 Data Analysis

2.4.1 Mountain sucker density in a reach – The density of mountain sucker will be estimated for each reach sampled for abundance monitoring. Mountain sucker abundance will first be estimated for each reach, and then converted into a density estimate. Abundance can be estimated using a variable probability removal estimator in Program CAPTURE (White et al. 1982); this estimator is model M(bh) in Otis et al. (1978). Program CAPTURE is available on the Internet as a web-based version at:

http://www.mbr-pwrc.usgs.gov/software/capture.html. Sample code for running the program and variable probability estimator is:

```
task read population  removal
5,'Ephemeroptera, stream insect. (data:u1,u2,u3,u4,u5)'
181,11,4,5,3
```

Lines 2 and 3 of this code can be changed to reflect reach-specific data, and then all 3 lines of code can be pasted into the Program CAPTURE input screen and run. In code line 2, “5” indicates the number of removal periods (electrofishing passes) followed by an output title in single quotations. Line 3 is the number of mountain suckers sampled during each removal period. Program CAPTURE will output an estimate of abundance $\hat{N}$; standard error, SE = $\sqrt{V\hat{a}r}$; and a profile likelihood confidence interval. Other computer software that estimates abundance with a measure of precision using a removal estimator can be used: MicroFish (http://microfish.org/ ; VanDeventer and Platts 1989) or Pop/Pro (http://www4.ncsu.edu/~tkwak/pp.html ; Kwak 1992). Often, large fish are captured more effectively by electrofishing than small fish. Thus, abundance should be estimated separately for each size class, if possible, and then summed to remove the effect of size bias (Kwak 1992); variances for size classes are also added to estimate total variance. Age-0 mountain sucker should be excluded from abundance estimates because they can be difficult to sample with electrofishing and because their abundances can vary widely among years and prohibit trend detection. Abundance estimates can be converted into densities (N/ha) using reach area.

2.4.2 Trends in mountain sucker density – Forest-wide trends in mountain sucker density will be estimated. First, trends in densities are estimated for each abundance site. Trends for each site are estimated by regressing the $\log_e(\text{density}^1 + 1)$ on year and determining the slope coefficient for this relationship. Using the $\log_e$-abundance is appropriate because animal abundances often change by some percentage each time unit (e.g., 2% decline per year) rather than changing by a constant amount (e.g., a decline of 20 fish/ha per year) (Thompson et al. 1998). By using $\log_e$-density, the slope of the regression line $\hat{b}_{1i}$ is an estimate of the percent annual change in the population when slope estimates are small (<0.20), and $\exp(\hat{b}_{1i}) \times 100$ estimates the percentage of individuals in the population at time *i* that remain at time *i* + 1 (Thompson et al. 1998). After trends are estimated for each site, then trends (i.e., slope coefficients) are averaged across sites to estimate average trend among the abundance sites.

For each abundance site, the $\log_e(\text{density} + 1)$ is calculated for each year and then regressed versus year to estimate trend:

$$\log_e\left(\hat{D}_{ij} + 1\right) = b_{0i} + b_{1i}\left(Year_j\right)$$

where $\hat{D}_{ij}$ = the estimated mountain sucker density for site *i* in year *j*. The regression slope estimates ($\hat{b}_{1i}$; approximate estimate of percent annual change) for each site *i* will then be used to compute a mean slope $\hat{\bar{b}}_1$ among abundance sites:

$$\hat{\bar{b}}_1 = \frac{\sum_{i=1}^{n} \hat{b}_{1i}}{n}$$

---

1 It is recommended that density be expressed as the number of mountain sucker per hectare (N/ha) so that adding a constant of 1 will result in little change in the density value. However, if it is desired that density be expressed on a different scale, such as N/m^2, then a smaller constant should be added (e.g., 0.01). A constant needs to be added to the density estimate because there is no natural logarithm for a density of zero if no mountain suckers are collected at a site.

where $\hat{b}_{1i}$ = regression slope estimate (approximately equivalent to percent annual change) for site *i*, and *n* is the number of sampling units (abundance sites) sampled. The variance estimate for mean slope $s^2_{\hat{\bar{b}}_1}$ is calculated as:

$$s^2_{\hat{\bar{b}}_1} = \frac{\sum_{i=1}^{n}\left(\hat{b}_{1i} - \hat{\bar{b}}_1\right)^2}{n-1}$$

where $\hat{b}_{1i}$, $\hat{\bar{b}}_1$, and *n* are as defined above. The variance estimate can be used to compute a confidence interval for the mean slope $\hat{\bar{b}}_1$ estimate. The lower confidence limit is:

$$\hat{\bar{b}}_1 - \mathrm{t}_{n-1,\alpha} \times \sqrt{s^2_{\hat{\bar{b}}_1} / n}$$

and the upper limit is:

$$\hat{\bar{b}}_1 + \mathrm{t}_{n-1,\alpha} \times \sqrt{s^2_{\hat{\bar{b}}_1} / n}$$

Where $\hat{\bar{b}}_1$, $s^2_{\hat{\bar{b}}_1}$, and *n* are as before, and $\mathrm{t}_{n-1,\alpha}$ = the t-value from a t distribution table with n-1 degrees of freedom and specified α. One can be 100(1 – α)% sure that the true but unknown mean annual change in mountain sucker abundance is within this interval.

A one-tailed t-test can be used to determine if the mean slope $\hat{\bar{b}}$ is significantly less than zero. A Type I error rate of α = 0.20 is recommended over a more conservative rate (e.g., α = 0.05) to reduce the chance of missing a decline that is real (Type II error). However, a higher Type I error rate will, by definition, increase the risk of detecting false changes. Type I and II error rates are inversely related, but not proportional. Management context will determine what are acceptable levels of each risk (Mulder et al. 1999). If the slope is significantly less than 0 and the estimated mean slope is -0.025

(equivalent to a 2.5% annual decline) or less, then management action should be taken to examine causes for population decline.

2.4.3 Distribution of mountain sucker – The distribution of mountain sucker will be monitored in watersheds distributed across the Black Hills National Forest. The distribution of mountain sucker will be determined first for each monitoring period, followed by an analysis of trends in distribution over time. To determine the distribution of mountain sucker per monitoring period, the proportion of sampling units (watersheds) occupied by mountain sucker is computed for each monitoring year. Then, the proportion occupied is logit-transformed ($\log_e[p/1 - p]$) and regressed on year; the logit-proportion occupied is used so that the proportion occupied is bound between zero and one as it changes in response to time.

After each monitoring period the forest-wide proportion of sampling units (i.e., watersheds) occupied by mountain sucker $\hat{p}$ is computed as:

$$\hat{p} = \frac{\sum_{i=1}^{n} y_i}{n}$$

where y_i = the presence (presence = 1, absence = 0) of mountain sucker in sampling unit i, and n = the number of sampling units sampled.

The variance for the estimated proportion $s_{\hat{p}}^2$ is:

$$s_{\hat{p}}^2 = \frac{\hat{p}(1-\hat{p})}{n}\left(\frac{N-n}{N}\right)$$

where $\hat{p}$ and n are as defined above, and N = number of sampling units in the sampling frame. The expression $\left(\frac{N-n}{N}\right)$ is a finite population correction factor that is used to reduce variance according to the proportion of the sampling frame included in the sample; 30 watersheds out of 184 watersheds in the sampling frame were selected for MIS monitoring. Although the variance is not used directly used in detecting changes in mountain sucker distribution, it is recommended that a measure of precision be reported for the proportion of sampling units that have mountain sucker present for each monitoring time period.

2.4.4 Trends in distribution of mountain sucker – After forest-wide estimates are computed for a monitoring time period, time trends in the proportion of sampling units occupied by mountain sucker can be determined. Logistic regression can be used whereby the proportion of sampling units occupied $\hat{p}_k$ for years 1 through k will be logit-transformed and regressed on year:

$$\log_e\left(\hat{p}_k/1-\hat{p}_k\right)=b_0+b_1\left(year_k\right)$$

A statistical software package that performs logistic regression should be used to account for the correct variation behavior of $\hat{p}_k$, as opposed to regressing logit of $\hat{p}_k$ versus time using least squares methods (Hosmer and Lemeshow 2000). The statistical test of interest is whether the estimated rate of change b_1 is significantly different from zero, using a two-tailed t-test. The parameter b_1 is the change in the log-odds of a watershed having mountain sucker present, and exp(b_1) is the annual increase or decrease in the odds a watershed having mountain sucker present per year. A two-tailed test is used to determine whether b_1 is less than or greater than zero because both increasing and decreasing trends in mountain sucker distribution are of interest. Again, a Type I error rate of $\alpha = 0.20$ is recommended, but it should be set according to the risks associated with making a Type I versus a Type II statistical error. When conducting the statistical test, a finite population correction should be applied to the variance estimate (and subsequently the standard error estimate) for b_1 because 30 of the 184 watersheds in the sample frame are included in the sample. As above, the finite population correction is multiplied by the variance estimate: $s^2_{\hat{b}_1}$ $(N - n / N)$. If the slope is significantly less than or greater than 0 and the estimated mean slope is ±0.069 (equivalent to 2-fold increase or decrease in the odds of a watershed having mountain present after 10 years; exp[0.069 × 10] = 2, exp[-0.069 × 10] = 0.5), then management action should be taken to examine causes for the change in distribution.

2.4.5 Trends in aquatic habitat – The protocol for estimating trends in attributes of aquatic habitat is similar to that for estimating trends in mountain sucker abundance. That is, trends in an attribute will be estimated for each site, then an average of trends across sites will be computed. All habitat attributes will be analyzed in this manner. For simplicity, the measurement of an attribute is referred to as X. Trends for each attribute are estimated by regressing the $\log_e(X + 1)$ on year and determining the slope coefficient for this relationship. By using the $\log_e$ of X, the slope of the regression line provides an estimate of percent change per time unit (e.g., 2% decline per year). Like population abundance, habitat attributes are expected to show a proportional change across time and not an absolute change (Larsen et al. 2004). However, if a specific habitat attribute is expected to show a constant change, then the value of that attribute should not be $\log_e$-transformed prior to regressing it on year. After trends are estimated for each site, then trends (i.e., slope coefficients) are averaged across sites to estimate average trend.

For each site, the $\log_e(X + 1)$ is calculated for each year and then regressed versus year to estimate trend:

$$\log_e\left(\hat{X}_{ij} + 1\right) = b_{0i} + b_{1i}\left(Year_j\right)$$

where $\hat{X}_{ij}$ = the estimated value for the habitat attribute for site *i* in year *j*. The regression slope estimates ($\hat{b}_{1i}$; approximate estimates of percent annual change) for each site *i* will then be used to compute a mean slope $\hat{\bar{b}}_1$ for the attribute across all sites:

$$\hat{\bar{b}}_1 = \frac{\sum_{i=1}^{n} \hat{b}_{1i}}{n}$$

where $\hat{b}_{1i}$ = regression slope estimate (approximately equivalent to percent annual change) for site *i*, and *n* is the number of sampling units (sites) sampled. The variance estimate for mean slope $s^2_{\hat{\bar{b}}_1}$ is calculated as:

$$s^2_{\hat{\bar{b}}_1} = \frac{\sum_{i=1}^{n} \left(\hat{b}_{1i} - \hat{\bar{b}}_1\right)^2}{n-1}$$

where $\hat{b}_{1i}$, $\hat{\bar{b}}_1$, and *n* are as defined above. The variance estimate can be used to compute a confidence interval for the mean slope $\hat{\bar{b}}_1$ estimate. The lower confidence limit is:

$$\hat{\bar{b}}_1 - t_{n-1,\alpha} \times \sqrt{s^2_{\hat{\bar{b}}_1} / n}$$

and the upper limit is:

$$\hat{\bar{b}}_1 + t_{n-1,\alpha} \times \sqrt{s^2_{\hat{\bar{b}}_1} / n}$$

Where $\hat{\bar{b}}_1$, $s^2_{\hat{\bar{b}}_1}$, and n are as before, and $t_{n-1,\alpha}$ = the t-value from a t distribution table with n-1 degrees of freedom and specified α. This interval indicates that one can be 100(1 – α)% sure that the true but unknown mean trend in the habitat attribute is within this interval.

As before, a one or two-tailed t-test can be used to determine if the mean slope $\hat{\bar{b}}$ is significantly different from zero. A one- or two-tailed test can be applied depending on whether an increasing, decreasing, or both increasing and decreasing trends are of interest for a specific aquatic habitat attribute. A Type I error rate of $\alpha = 0.20$ is recommended over a more conservative rate (e.g., $\alpha = 0.05$) to reduce the chance of missing a real change in habitat (Type II error). If the slope is significantly different from 0, and the estimated mean slope is ±0.025 (approximately equivalent to a 2.5% annual change), then management action should be taken to examine causes for habitat change.

2.4.6 Trends in habitat connectivity – Forest-wide trends in aquatic habitat connectivity will be measured directly by documenting the number of barriers improved to facilitate movement of aquatic organisms. Because the number of barriers removed over time will be known, statistical tests are not needed to make inferences regarding forest-wide trends in the improvement of barriers. It is assumed that improvements to barriers will improve stream connectivity. Therefore, trends in stream connectivity will be monitored by plotting the cumulative number of barriers improved over time (Figure 7).

2.5 Reporting

2.5.1 Expected Reports – Results will be reported in a Monitoring and Evaluation Report completed after each monitoring year. Monitoring and Evaluation Reports will describe what monitoring was completed and report a summary of monitoring results from the standpoint of monitoring objectives. Each report should summarize fish population and stream habitat data collected at each sample reach. After the first 10 years of monitoring, the Monitoring and Evaluation Report should also report results for trends in abundance and distribution of the mountain sucker and also results for trends in aquatic habitats. These reports should also recommend how the results might be used to improve or validate forest management planning.

2.5.2 Reporting Schedule – Monitoring and Evaluation Reports are generated for each monitoring period. Monitoring will be implemented by the biologist for the Black Hills National Forest that coordinates MIS monitoring, and results for aquatic MIS monitoring should be reported in the first Monitoring and Evaluation Report after a monitoring year. This will equate to reporting results for abundance monitoring and aquatic habitat monitoring every three years. Results for distribution monitoring should be reported every five years and at least every 10 years.

References

Archer, E. K., B. B. Roper, R. C. Henderson, N. Bouwes, S. C. Mellison, and J. L. Kershner. 2004. Testing common stream sampling methods for broad-scale, long-term monitoring. United States Department of Agriculture, Forest Service, Rocky Mountain Research Station, General Technical Report RMRS-GTR-122, Fort Collins, Colorado.

Baxter, G. T., and M. D. Stone. 1995. Fishes of Wyoming. Wyoming Game and Fish Department, Cheyenne.

Bayley, P. B., and J. T. Peterson. 2001. An approach to estimating probability of presence and richness of fish species. Transactions of the American Fisheries Society 130:620-633.

Belica, L. T., and N. P. Nibbelink. 2006. Mountain sucker (*Catostomus platyrhynchus*): a technical conservation assessment. USDA Forest Service, Rocky Mountain Region, http://www.fs.fed.us/r2/projects/scp/assessments/mountainsucker.pdf.

Boyce, M. S., P. R. Vernier, S. E. Nielsen, and F. K. A. Schmiegelow. 2002. Evaluating resource selection functions. Ecological Modelling 157:281-300.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information - theoretic approach, Second ed. Springer-Verlag, New York.

Burton, T. A., E. R. Crowley, and S. J. Smith. 2007. Monitoring streambanks and riparian vegetation -- multiple indicators. Idaho State Office, Bureau of Land Management and Intermountain Region, U.S. Forest Service, Idaho Technical Bulletin No. 2007-01, Boise, Idaho.

Campbell, R. E. 1992. Status of the mountain sucker, *Catostomus platyrhynchus*, in Canada. Canadian Field Naturalist 106:27-35.

Clarkin, K., A. Connor, M. J. Furniss, B. Gubernick, M. Love, K. Moynan, and S. WilsonMusser. 2005. National inventory and assessment procedure - for identifying barriers to aquatic organism passage at road-stream crossings. United States Department of Agriculture, Forest Service, National Technology and Development Program, http://www.stream.fs.fed.us/publications/PDFs/NIAP.pdf, 7700-Transport Management, San Dimas, California.

Cochran, W. G. 1977. Sampling techniques. John Wiley & Sons, New York.

Dauwalter, D. C., and W. L. Fisher. 2007. Electrofishing capture probability of smallmouth bass in streams. North American Journal of Fisheries Management 27:162-171.

Dauwalter, D. C., W. L. Fisher, and K. C. Belt. 2006. Mapping stream habitats with a global positioning system: accuracy, precision, and comparison with traditional methods. Environmental Management 37:271-280.

Dauwalter, D. C., D. K. Splinter, W. L. Fisher, and R. A. Marston. 2007. Geomorphology and stream habitat relationships with smallmouth bass abundance at multiple spatial scales in eastern Oklahoma. Canadian Journal of Fisheries and Aquatic Sciences 64:1116-1129.

Decker, L. M. 1989. Coexistence of two species of sucker, *Catostomus*, in Sagehen Creek, California, and notes on their status in the western Lahontan Basin. Great Basin Naturalist 49:540-551.

Decker, L. M., and D. C. Erman. 1992. Short-term seasonal changes in composition and abundance of fish in Sagehen Creek, California. Transactions of the American Fisheries Society 121:297-306.

Dunham, A. E., G. R. Smith, and J. N. Taylor. 1979. Evidence for ecological character displacement in western American catostomid fishes. Evolution 33:877-896.

Evermann, B. W. 1893. The ichthyologic features of the Black Hills region. Proceedings of the Indiana Academy of Sciences 1892:73-78.

Evermann, B. W., and U. O. Cox. 1896. A report upon the fishes of the Missouri River basin. Report to the U.S. Commission on Fish and Fisheries 20(1984),

Filipe, A. F., I. G. Cowx, and M. J. Collares-Pereira. 2002. Spatial modeling of freshwater fish in semi-arid river systems: a tool for conservation. River Research and Applications 18:123-136.

Ford, R. C. 1988. Black Hills stream inventory and classification, 1984 and 1985. South Dakota Department of Game, Fish, and Parks, Report Number 88-1, Pierre, South Dakota.

Gibbs, J. P. 2000. Monitoring populations. Pages 213-252 *in* L. Boitani and T. K. Fuller, editors. Research techniques in animal ecology. Columbia University Press, New York, New York.

Gibbs, J. P., S. Droege, and P. Eagle. 1998. Monitoring populations of plants and animals. BioScience 48:935-940.

Ham, K. D., and T. N. Pearsons. 2000. Can reduced salmonid population abundance be detected in time to limit management impacts? Canadian Journal of Fisheries and Aquatic Sciences 57:17-24.

Harrelson, C. C., C. L. Rawlins, and J. P. Potyondy. 1994. Stream channel reference sites: an illustrated guide to field technique. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-245, Fort Collins, Colorado, http://www.fs.fed.us/rm/pubs_rm/rm_gtr245.pdf.

Hauser, W. J. 1969. Life history of the mountain sucker, *Catostomus platyrhynchus*, in Montana. Transactions of the American Fisheries Society 2:209-215.

Hosmer, D. W., and S. Lemeshow. 2000. Applied logistic regression, second ed. John Wiley & Sons, Inc., New York.

Isaak, D. J., and W. A. Hubert. 2000. Are trout populations affected by reach-scale stream slope? Canadian Journal of Fisheries and Aquatic Sciences 57:468-477.

Isaak, D. J., W. A. Hubert, and C. R. Berry, Jr. 2003. Conservation assessment for lake chub, mountain sucker, and finescale dace in the Black Hills National Forest, South Dakota and Wyoming. U. S. Department of Agriculture, Forest Service, Rocky Mountain Region, Black Hills National Forest, Custer, South Dakota, http://www.fs.fed.us/r2/blackhills/projects/planning/assessments/chub_sucker_dace.pdf.

Johnson, D. H. 1999. The insignificance of statistical significance testing. Journal of Wildlife Management 63:763-772.

Knighton, D. 1998. Fluvial forms and processes: a new perspective. Oxford University Press, Inc., New York.

Kwak, T. J. 1992. Modular microcomputer software to estimate fish population parameters, production rates and associated variance. Ecology of Freshwater Fish 1:73-75.

Larsen, D. P., P. R. Kaufmann, T. M. Kincaid, and N. S. Urquhart. 2004. Detecting persistent change in the habitat of salmon-bearing streams in the Pacific Northwest. Canadian Journal of Fisheries and Aquatic Sciences 61:283-291.

Larsen, D. P., T. M. Kincaid, S. E. Jacobs, and N. S. Urquhart. 2001. Designs for evaluating local and regional scale trends. BioScience 61:1069-1078.

Meester, R. J. 1993. Statewide fisheries surveys, 1992, surveys of public waters: part 2 streams. South Dakota Department of Game, Fish, and Parks, Annual Report Number 93, Pierre, South Dakota.

Mulder, B. S., B. R. Noon, T. A. Spies, M. G. Raphael, C. J. Palmer, A. R. Olsen, G. H. Reeves, and H. H. Welsh. 1999. The strategy and design of the effectiveness monitoring program for the Northwest Forest Plan. U.S. Department of Agriculture, Forest Service, Northwest Research Station, General Technical Report PNW-GTR-437, Portland, Oregon.

Olden, J. D., D. A. Jackson, and P. R. Peres-Neto. 2002. Predictive models of fish species distributions: a note on proper validation and chance predictions. Transactions of the American Fisheries Society 131:329-336.

Otis, D. L., K. P. Burnham, G. C. White, and D. R. Anderson. 1978. Statistical inference from capture data on closed animal populations. Wildlife Monographs 62:1-135.

Patton, T. M., F. J. Rahel, and W. A. Hubert. 1998. Using historical data to assess changes in Wyoming's fish fauna. Conservation Biology 12:1120-1128.

Pearce, J., and S. Ferrier. 2000. Evaluating the predictive performance of habitat models developed using logistic regression. Ecological Modelling 133:225-245.

Peterson, J. T., R. F. Thurow, and J. W. Guzevich. 2004. An evaluation of multipass electrofishing for estimating the abundance of stream-dwelling salmonids. Transactions of the American Fisheries Society 133:462-475.

Potyondy, J. P., and T. Hardy. 1994. Use of pebble counts to evaluate fine sediment increase in stream channels. Water Resources Bulletin 30:509-520.

Potyondy, J. P., B. B. Roper, S. E. Hixson, R. L. Leiby, R. L. Lorenz, and C. M. Knopp. 2006. Aquatic ecological unit and inventory technical guide: valley segment and river reach. U.S. Department of Agriculture, Forest Service, Washington Office, Ecosystem Management Coordination Staff, General Technical Report [Draft], Washington, DC.

Rahel, F. J., and N. P. Nibbelink. 1999. Spatial patterns in relations among brown trout (*Salmo trutta*) distribution, summer air temperature, and stream size in Rocky Mountain streams. Canadian Journal of Fisheries and Aquatic Sciences 56:43-51.

Riley, S. C., and K. D. Fausch. 1992. Underestimation of trout population size by maximum-likelihood removal estimates in streams. North American Journal of Fisheries Management 12:768-776.

Riley, S. C., R. L. Haedrich, and R. J. Gibson. 1993. Negative bias in removal estimates of Atlantic salmon parr relative to stream size. Journal of Freshwater Ecology 8:97-101.

Roper, B. B., J. L. Kershner, and R. C. Henderson. 2003. The value of using permanent sites when evaluating stream attributes at the reach scale. Journal of Freshwater Ecology 18:585-592.

Rosgen, D. L. 1996. Applied river morphology. Wildland Hydrology, Pagosa Springs, Colorado.

SAIC. 2005. Selection of management indicator species: Black Hills National Forest phase II plan amendment. Prepared for United States Department of Agriculture-

Forest Service, Black Hills National Forest by Science Applications International Corporation, Littleton, Colorado, http://www.fs.fed.us/r2/blackhills/projects/planning/assessments/saic_2005_mis_selection.pdf.

SDGFP. 2006. South Dakota Comprehensive Wildlife Conservation Plan. South Dakota Department of Game, Fish, and Parks, Wildlife Division Report 2006-08, Pierre, http://www.sdgfp.info/Wildlife/Diversity/Comp_Plan/SDCompplan.pdf.

Smith, G. R. 1966. Distribution and evolution of the North American catostomid fishes of the subgenus *Pantosteus*, genus *Catostomus*. Miscellaneous publications, Museum of Zoology, University of Michigan, No. 129, Ann Arbor, Michigan.

Steen, P. J., D. R. Passino-Reader, and M. J. Wiley. 2006. Modeling brook trout presence and absence from landscape variables using four different analytical methods. Pages 513-531 *in* R. M. Hughes, L. Wang, and P. W. Seelbach, editors. American Fisheries Society, Symposium 48. Bethesda, Maryland.

Stewart, R. K., and C. A. Thilenius. 1964. Stream and lake inventory and classification in the Black Hills of South Dakota. South Dakota Department of Game, Fish, and Parks, Dingell-Johnson Project F-1-R-13, Job Numbers 14 and 15, Pierre, South Dakota.

Strahler, A. N. 1957. Quantitative analysis of watershed geomorphology. Transactions of the American Geophysical Union 38:913-920.

Thompson, W. L., G. C. White, and C. Gowan. 1998. Monitoring vertebrate populations. Academic Press, San Diego, California.

Travnichek, V. H., M. B. Bain, and M. J. Maceina. 1995. Recovery of a warmwater fish assemblage after the initiation of a minimum-flow release downstream from a hydroelectric dam. Transactions of the American Fisheries Society 124:836-844.

Urquhart, N. S., and T. M. Kincaid. 1999. Designs for detecting trend from repeated surveys of ecological resources. Journal of Agricultural, Biological, and Environmental Statistics 4:404-414.

USDA Forest Service. 2005a. Black Hills National Forest land and resource management plan: phase II amendment. United States Department of Agriculture, Forest Service, Rocky Mountain Region, Custer, South Dakota, http://www.fs.fed.us/r2/blackhills/projects/planning/index.shtml.

USDA Forest Service. 2005b. Guide to identification of bankfull stage in the northeastern United States. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, General Technical Report RMRS-GTR-133-CD. 4 CD-ROM set, Fort Collins, CO.

USDA Forest Service. 2007. FY2006 monitoring and evaluation report. United States Department of Agriculture, Forest Service, Black Hills National Forest, Custer, South Dakota, http://www.fs.fed.us/r2/blackhills/projects/planning/fy2006_report.pdf.

VanDeventer, J. J., and W. S. Platts. 1989. MicroFish 3.0. Intermountain Research Station, INT-254, Boise, Idaho.

Vannote, R. L., G. W. Minshall, K. W. Cummins, and C. E. Cushing. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37:130-137.

Vesely, D., B. C. McComb, C. D. Vojta, L. H. Suring, J. Halaj, R. S. Holthausen, B. Zuckerberg, and P. M. Manley. 2006. Development of protocols to inventory or monitor wildlife, fish, or rare plants. U.S. Department of Agriculture, Forest Service, General Technical Report WO-72, Washington, D.C., http://www.fs.fed.us/biology/wildecology/SpProtocolTechGuide.pdf.

WGFD. 2005. A comprehensive wildlife conservation strategy for Wyoming. Wyoming Game and Fish Department, Cheyenne, Wyoming, http://www.wildlifeactionplans.org/pdfs/action_plans/wy_action_plan.pdf.

White, G. C., D. R. Anderson, K. P. Burnham, and D. L. Otis. 1982. Capture-recapture and removal methods for sampling closed populations. Los Alamos National Laboratory, LA-8787-NERP, Los Alamos, New Mexico.

Wolman, M. G. 1954. A method of sampling coarse river-bed material. Transactions of the American Geophysical Union 35:951-956.

Wydoski, R. G., and R. S. Wydoski. 2002. Age, growth, and reproduction of mountain suckers in Lost Creek Reservoir, Utah. Transactions of the American Fisheries Society 131:320-328.

Yant, P. R., J. R. Karr, and P. L. Angermeier. 1984. Stochasticity in stream fish communities: an alternative interpretation. American Naturalist 124:573-582.

Zippin, C. 1958. The removal method of population estimation. Journal of Wildlife Management 22:82-90.

Table 1. Design components for the four mountain sucker population and aquatic habitat metrics being monitored on the Black Hills National Forest.

Metric	Design component	Definition
1. Mean percent annual decline in mountain sucker density	Target Population	All stream sites
	Sampled Population	Sites where mountain sucker historically occurred
	Sampling Frame	Sites sampled since 1984 which had mountain sucker
	Sample	Selected sites
	Sampling Unit	Site
	Element	Site
2. Change in the odds of a watershed having mountain sucker present	Target Population	All 8th level watersheds predominantly NFS land
	Sampled Population	All 8th level watersheds predominantly NFS land
	Sampling Frame	All 8th level watersheds predominantly NFS land
	Sample	Selected 8th level watersheds
	Sampling Unit	8th level watershed
	Element	8th level watershed
3. Mean percent annual change in habitat attribute X[a]	Target Population	All stream sites
	Sampled Population	Sites where mountain sucker historically occurred
	Sampling Frame	Sites sampled since 1984 which had mountain sucker
	Sample	Selected sites
	Sampling Unit	Site
	Element	Site
4. Cumulative number of barriers to fish movement improved	Target Population	All barriers on the Forest
	Sampling Frame	All barriers on the Forest
	Sampled Population	All barriers on the Forest
	Sample	All barriers on the Forest
	Sampling Unit	Barrier
	Element	Barrier

[a] Multiple aquatic habitat attributes will be monitored

Table 2. Sites selected for monitoring mountain sucker abundance and aquatic habitat on the Black Hills National Forest, South Dakota and Wyoming. Universal Transverse Mercator (UTM) Zone 13 coordinates for downstream locations of each site are given.

Site	Stream name	North	East
ANN03	Annie Creek	588207.8	4908813.5
BATTLE 9	Battle Creek	631692.1	4860782.0
BBC06	Bear Butte Creek	608101.8	4909219.0
BJC01	Bogus Jim Creek	626108.3	4886936.5
BOX01	Boxelder Creek	622796.6	4890399.5
BOXELDER 5	Boxelder Creek	617029.3	4895005.5
BXN02	North Boxelder Creek	603893.3	4897490.5
CAS06	Castle Creek	600269.5	4880902.0
CASTLE 4	Castle Creek	586950.1	4881332.0
CCN03	Castle Creek North	596802.4	4882154.5
DRC01	Deer Creek	620890.4	4883642.0
ELK04	Elk Creek	609032.2	4903921.5
FRC08	French Creek	620291.3	4841668.0
HOC02	Horse Creek	621471.3	4871078.5
ICS02	Iron Creek South	623838.4	4853846.5
IRON SOUTH 13	Iron Creek South	633208.4	4853846.5
JIM02	Jim Creek	616064.0	4889078.5
MIDDLE BOXELDER 2	Middle Boxelder Creek	603788.8	4894591.0
RAP05	Rapid Creek	607907.3	4884529.5
RCN02	Rapid Creek North	596343.2	4884529.0
SLC01	Slate Creek	609906.8	4877237.0
SOUTH BOXELDER 6	South Boxelder Creek	614546.9	4894387.0
SPR06	Spring Creek	600723.4	4862113.0
SPRING 12	Spring Creek	611421.3	4859578.0
SWD02	Swede Gulch	597830.7	4892426.0
*	Beaver Creek above Cook Lk.		

*Site code, sampling location, and UTM coordinates to be determined.

Table 3. 8th level Hydrologic Unit Code watersheds selected for monitoring mountain distribution on the Black Hills National Forest, South Dakota and Wyoming. Stream reaches where mountain sucker are most likely to occur will be identified within watersheds for sampling. Watersheds with an asterisk need field reconnaissance to verify stream intermittency and sampling feasibility, and could be replaced with alternate watersheds. After sites are identified within watersheds, the geographic coordinates (UTM, Zone 13) should be recorded for the downstream location of each site.

8th level HUC	Stream name	North	East
1012020109060202	Beaver Creek		
1012011001060204	Castle Creek or Tributary		
1012020303020303	Spearfish Creek		
1012011001040302	Ditch Creek		
1012010905010403	Battle Creek		
1012011002010403	Rapid Creek (Dark Canyon)		
1012010906010103	Spring Creek		
1012011001010302	North Fork Rapid Creek		
1012011101010404	South Boxelder Creek		
1012020206010202*	Park Creek		
1012011001080101*	Kelly Gulch, Rapid Creek		
1012011001080201*	West Nugget Gulch		
1012020303010502	Ward Draw		
1012011101010303	Boxelder Creek		
1012020109060101	Whitelaw Creek		
1012011002010303	Prairie Creek		
1012010905010503	Iron Creek South		
1012011002010502*	South Victoria Creek		
1012011001040402	Nichols Creek		
1012010906010102	Spring Creek (headwaters)		
1012010906010302	Coon Creek		
1012010906040101*	Johnson Gulch		
1012011002010504	Victoria Creek		
1012010906030102	Horse Creek		
1012010903020102	Glen Erin Creek		
1012020303030203	Little Spearfish Creek		
1012020109060203	Beaver Creek		
1012011001030302	Rapid Creek (Benner – Bearcat)		
1012011001020202	South Fork Rapid Creek		
1012011001070302	Slate Creek (above dam)		

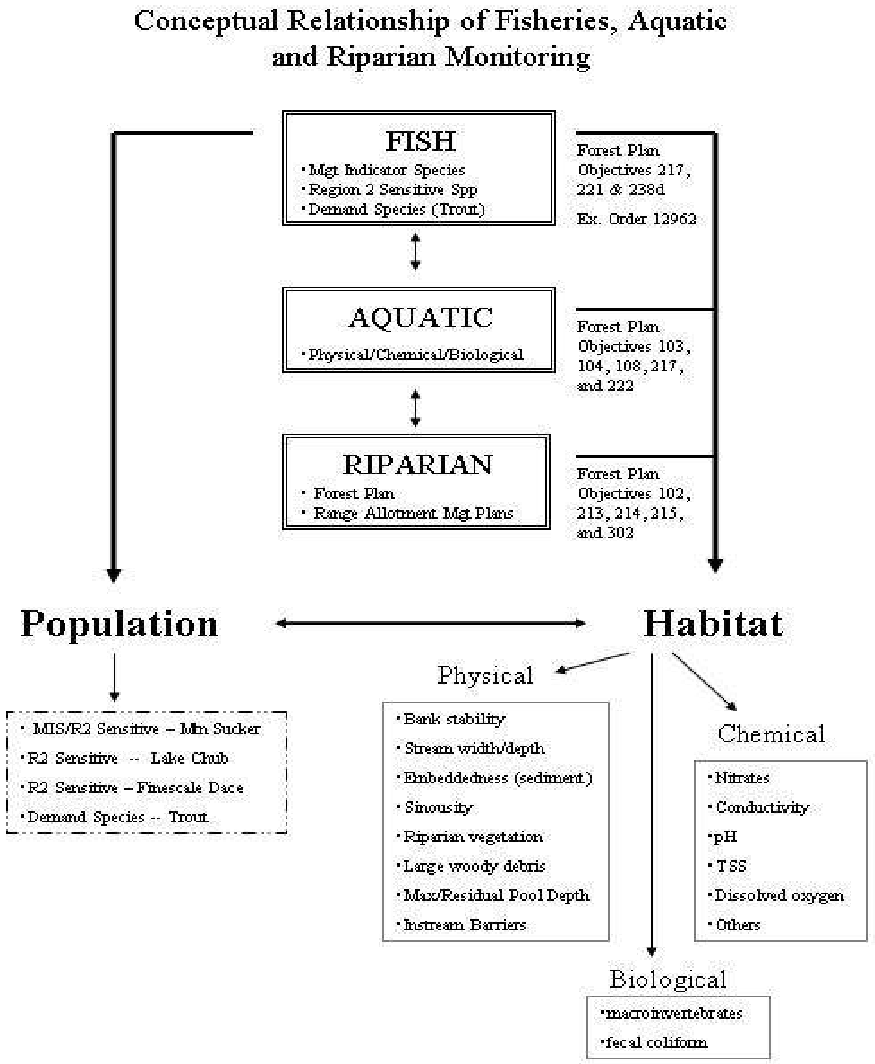


Figure 1. Conceptual model showing the interrelationships of Black Hills National Forest monitoring programs and objectives.

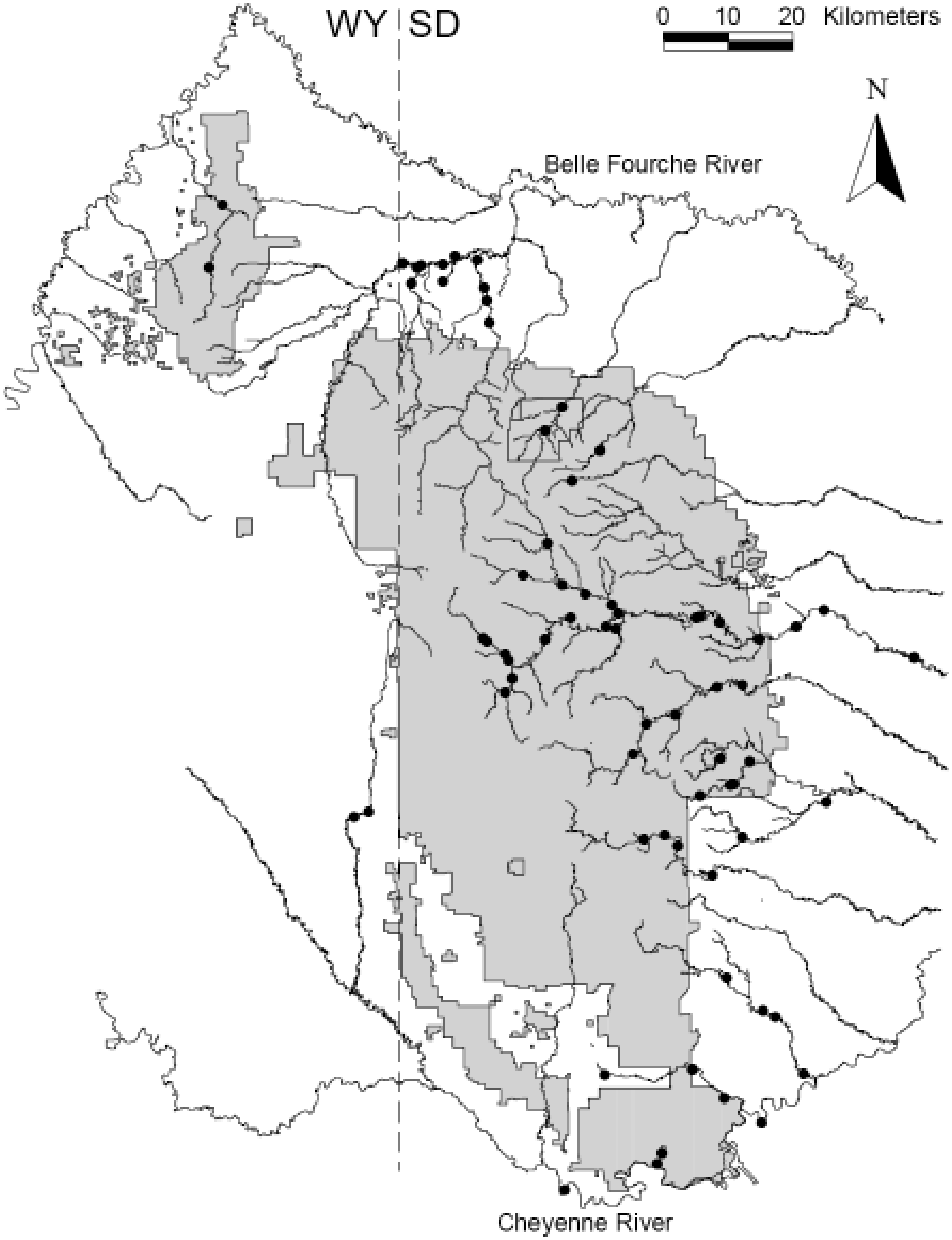


Figure 2. Known historical distribution (pre-1965) of mountain sucker around the Black Hills and the Black Hills National Forest, South Dakota and Wyoming (from Isaak et al. 2003).

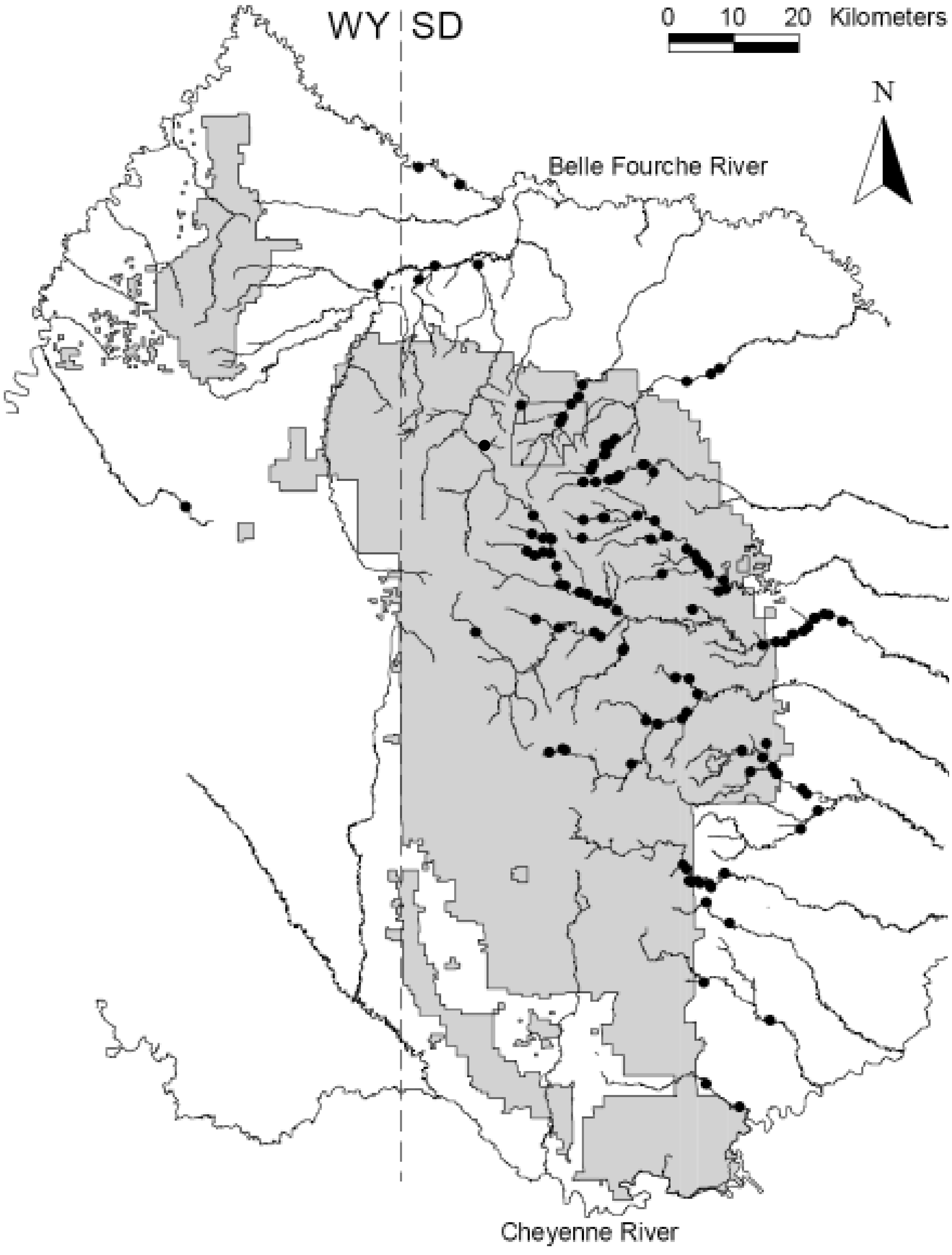


Figure 3. Known recent distribution (1984-Present) of mountain sucker in the Black Hills and the Black Hills National Forest, South Dakota and Wyoming (modified from Isaak et al. 2003).

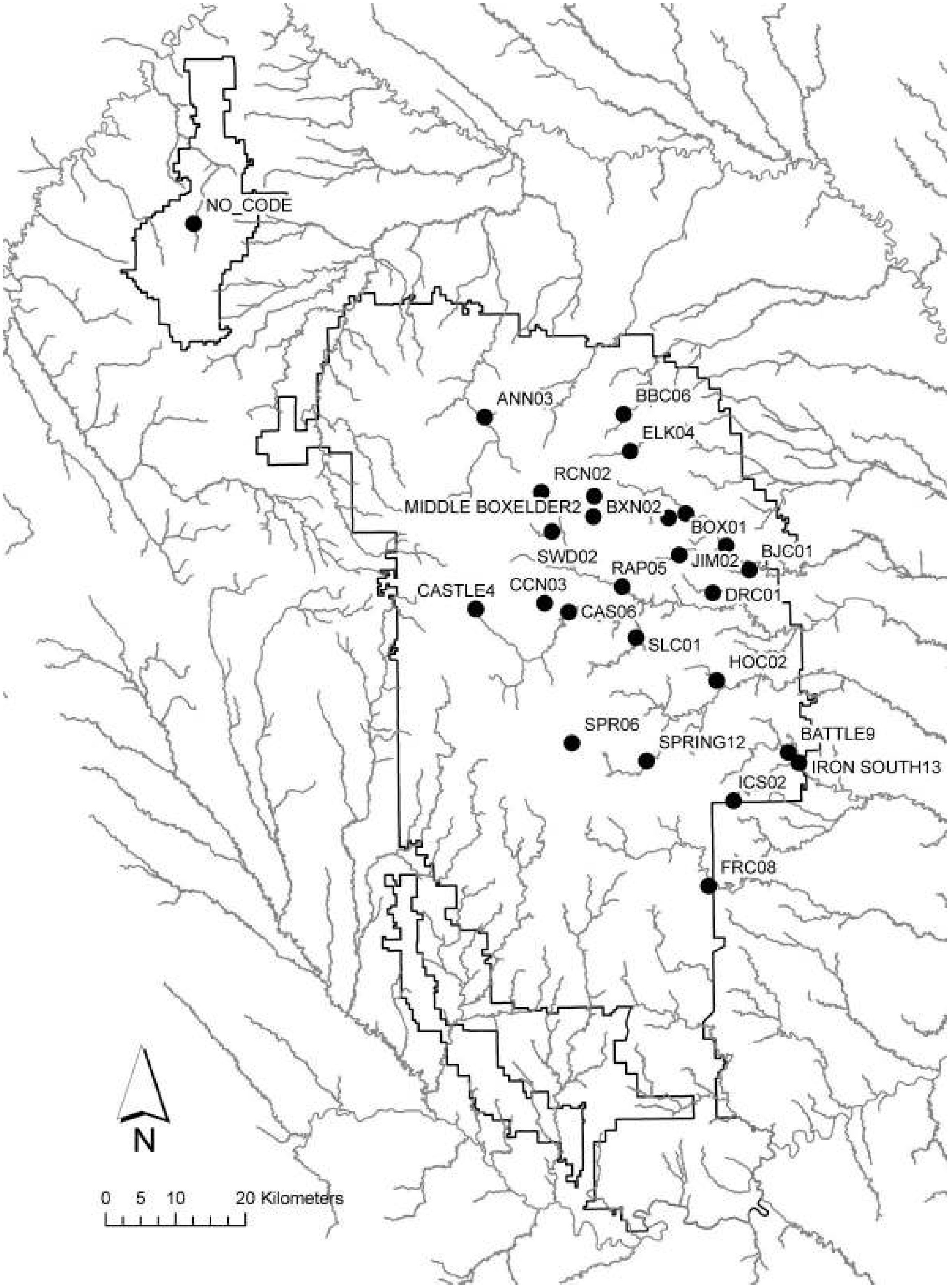


Figure 4. Stream sites selected for monitoring trends in mountain sucker abundance and aquatic habitat on the Black Hills National Forest, South Dakota and Wyoming. Stream codes are explained in Table 2.

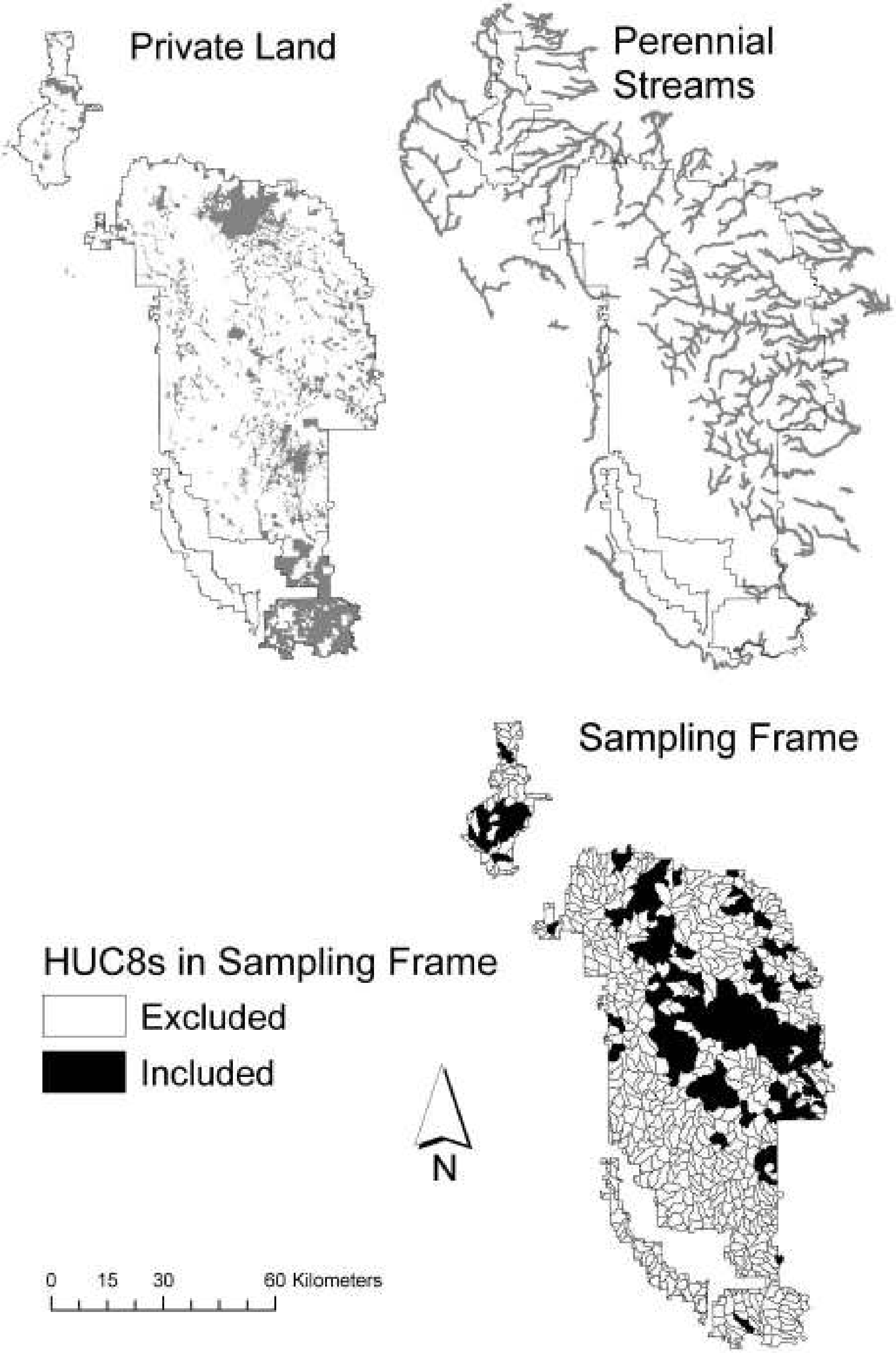


Figure 5. Location of perennial streams, private land, and 8th level Hydrologic Unit Code watersheds (HUC8s) on the Black Hills National Forest, South Dakota and Wyoming. Watersheds with perennial streams and >50% of perennial stream length on National Forest System land were included in the sampling frame of watersheds for monitoring trends in mountain sucker distribution over time.

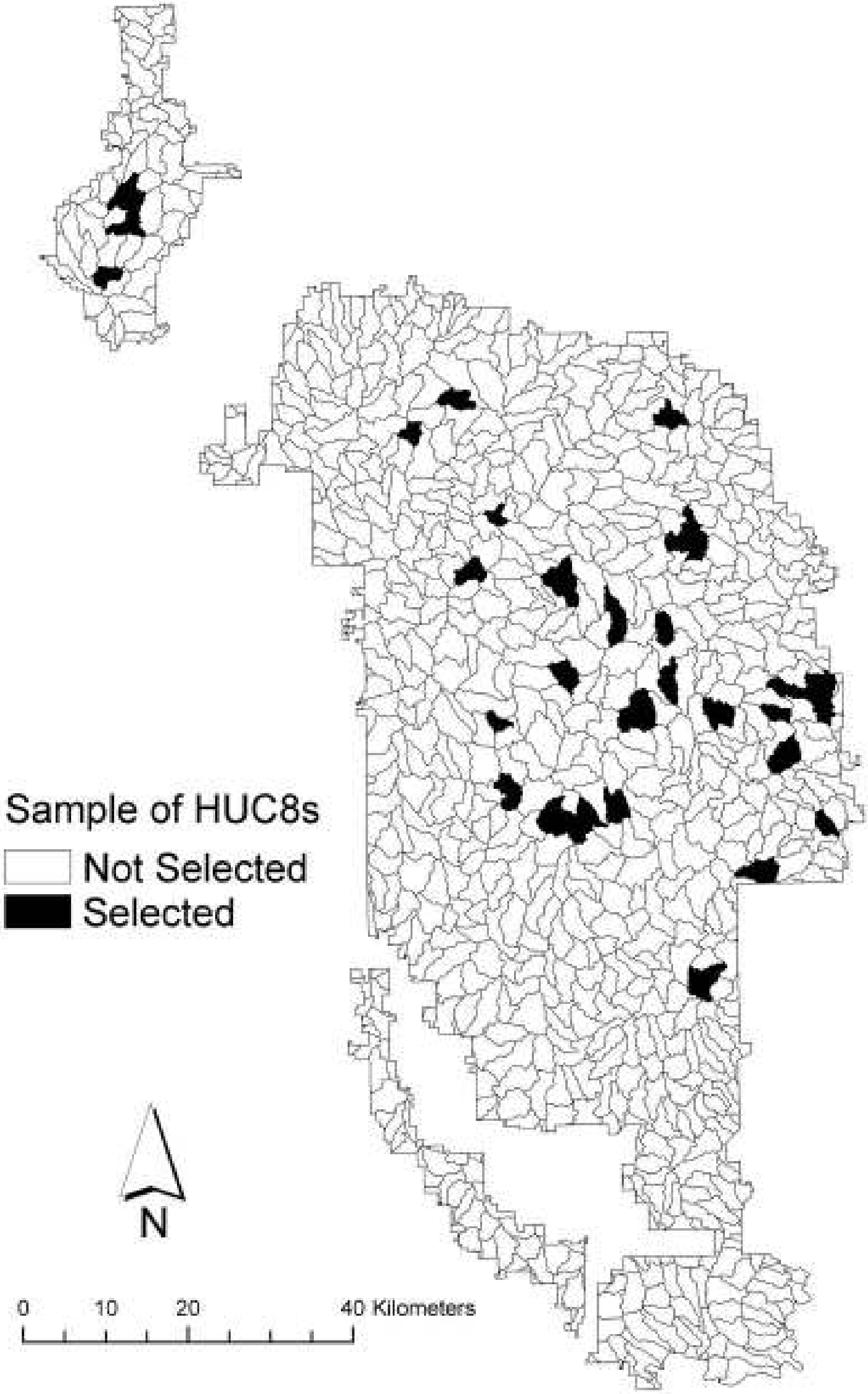


Figure 6. Sample of 8th level Hydrologic Unit Code watersheds randomly selected for monitoring trends in the distribution of mountain sucker over time on the Black Hills National Forest, South Dakota and Wyoming. Stream reaches within watersheds will be located where mountain sucker are most likely to occur. The list of selected watersheds and Hydrologic Unit Codes are presented in Table 3.

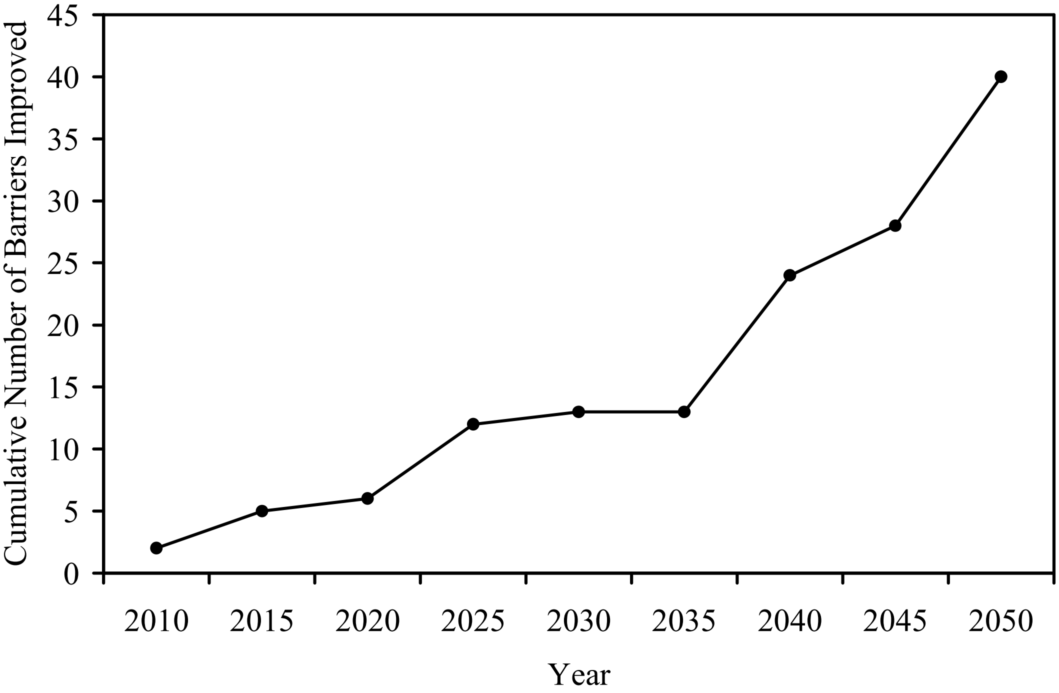


Figure 7. An example showing the cumulative number of barriers to movement improved to facilitate movement of aquatic organisms over time. This metric will represent the trend in stream connectivity for the Black Hills National Forest, South Dakota and Wyoming.

Appendix A. Temporal variation in mountain sucker populations, major sources of variation, population trends over time, and power to detect trends over time, Black Hills National Forest, South Dakota and Wyoming.

Management indicator species monitoring for the Black Hills National Forest is aimed, in part, at detecting changes in mountain sucker populations. The effectiveness of a monitoring program in detecting population trends is determined to some degree by the variability of population abundance over space and time. At a single site, observed variation can result from sampling error or true population variation over time. In a monitoring network of sites, variation in population abundance can be caused by 1) the unique characteristics of a site (site variation), 2) synchronous inter-annual variation among sites (coherent variation), 3) inter-annual variation unique to each site (interaction variation), and 4) sampling error, sampling variance, the time period when the population is sampled, and population variation within the time period of sampling (residual variation) (Larsen et al. 2001; Larsen et al. 2004). The variation in population abundance of salmonids and other fishes is average to slightly high when compared to other organisms with a variety of life history strategies (Gibbs et al. 1998), and this variation has been reported to hinder the detection of fish population trends (Ham and Pearsons 2000).

We quantified the variation in mountain sucker abundance and biomass over time, determined the major sources of that variation, evaluated whether mountain sucker abundance had changed over time, and determined the statistical power to detect trends in mountain sucker abundance on the Black Hills National Forest, South Dakota and Wyoming.

Methods

We used data from fish population surveys conducted on the Black Hills National Forest to evaluate variation in mountain sucker abundance and biomass, evaluate population trends over time, and determine whether or not population trends can be reliably detected. We used data from streams surveys conducted by the South Dakota Department of Game, Fish, and Parks from 1988 to 2004. They sampled fishes from 100-m stream reaches using multiple-pass backpack electrofishing. The abundance of each fish species was estimated using a removal estimator (Zippin 1958). We used data from 23 sites that were sampled at least 4 different years, and where variation in mountain sucker abundance was greater than zero.

Temporal variation in mountain sucker abundance and biomass was quantified as the coefficient of variation in abundance or biomass estimates over time. If a stream site was sampled more than once during a year, only data from the first sample were used.

We conducted variance partitioning to determine the major sources of variation in mountain sucker abundance and biomass. We used mountain sucker data from all sites, years, and samples within a year to partition total variation into site, coherent, interaction, and residual variance. Abundance and biomass data were log-transformed ($\log_e[X + 1]$) for analysis. Variance partitioning was done using a random effects model using PROC MIXED in SAS, Version 9.1 (SAS Institute, Inc., Cary, North Carolina).

We determined whether there was an overall trend in mountain sucker populations on the Black Hills National Forest. To estimate overall trends, we first estimated trend for an individual site by regressing $\log_e$-density or $\log_e$-standing stock on year. The slope estimate for each regression per site represents an estimate of percent annual change in density or standing stock. Then, overall trend was evaluated by computing the average trend across sites. A two-tailed t-test was used to determine if the overall trend among sites was significantly different from zero at $\alpha = 0.20$.

A prospective statistical power analysis was conducted to determine if a logistically feasible monitoring program has the ability to reliably detect trends in mountain sucker populations. The analysis followed the steps outlined by Gibbs (2000):

1. Define structure of monitoring program (number of sites, frequency of monitoring, duration of monitoring)
2. Simulate initial abundance for each site from defined spatial distribution of abundance
3. Project trend onto initial abundance per site for duration of monitoring
4. Abundance for each monitoring period at a site is a random deviate, with mean equal to projected abundance estimate and variance defined from a measure of temporal variation
5. The trend in abundance is estimated for each site using linear regression (i.e. slope of the regression line)
6. The mean and variance of trends among sites is calculated
7. A statistical test is used to determine whether the mean trend is significantly different from zero
8. Repeat steps 1 through 7 many times, and the proportion of repetitions in which the mean trend is significantly different from zero is determined. This proportion represents the statistical power to detect change (ranges from 0 to 1), and indicates how often the monitoring program correctly detects ongoing trends in abundance.

In order to apply this analysis process to the MIS monitoring design for the Black Hills National Forest we had to define the spatial and temporal variability to be simulated and use that data within the structure of the monitoring design to determine if trends could be detected. First, mean mountain sucker density (N/ha) per site was generated from a log-normal distribution (mean density = 31.1; SD = 27.8). Temporal variation was also randomly selected for each site based on a log-normal distribution of coefficients of variation of mountain sucker density (N/ha) over time (mean CV = 141.6; SD = 1.4). These distributions of spatial and temporal variation were defined using mountain sucker data for the Black Hills National Forest in the South Dakota Department of Game, Fish, and Parks fisheries database. Then, density was simulated for each time period (up to 30 years) for each site by first applying a time trend to the initial density per site (2.5% annual decline), and then adding random variation using the estimate of temporal variation. After abundance data were simulated for each time period for each site, $\log_e$-density was regressed on year to estimate trends in density over time for individual sites. A one-sample t-test was used to determine if the average trend among all sites was less than zero, employing a one-tailed test at two Type I error rates ($\alpha = 0.10$ or 0.20). This process was repeated 1,000 times, and statistical power was computed as the proportion of times that the known trends were detected. In essence, we were asking if we could detect a decline in mountain sucker density (mean of regression coefficients significantly less than zero) for a known percentage decline in the face of simulated year to year random variation in mountain sucker abundance. Power was evaluated for a time trend equivalent to a 2.5% annual decline, Type I error rates of 0.10 and 0.20, and up to 30 years of monitoring. Simulation analyses were conducted using SAS, version 9.1 statistical software (SAS Institute, Inc, Cary, North Carolina).

Results and Discussion

In the South Dakota Department of Game, Fish, and Parks database, there were fish collection data from 23 stream sites sampled four or more years between 1988 and 2004; sites were located on Annie Creek, Bear Butte Creek, French Creek, Rapid Creek, Strawberry Creek, and Whitewood Creek. The number of years sampled per site ranged from 4 years in Rapid Creek, site 35 to 13 years in Rapid Creek, site 07 and Bear Butte Creek, site 3. Mountain sucker densities ranged from 0/ha in multiple samples at several sites to 8344 / ha in Bear Butte Creek, site 14 in 2000. Maximum standing stock was 137.2 kg / ha in Whitewood Creek, site 09 in 2000.

Mountain sucker abundance and biomass was highly variable over time. The average CV in abundance among sites was 148% (SD = 47), and ranged from 75% in Whitewood Creek, site 01 to 265% in Whitewood Creek, site 21. Biomass also varied substantially, with the CV in standing stock (kg/ha) averaging 155% (SD = 53); the lowest CV was 86% in Whitewood Creek, site 01, but was 265% Whitewood Creek, site 21. Variation in population abundance of mountain sucker is high compared to trout populations (Gibbs et al. 1998). However, these abundance estimates might have included age-0 fishes that are typically considered highly variable in abundance from year to year (Yant et al. 1984). This might have caused the observed variability to be higher than if only age-1 and older mountain sucker were included in abundance estimates.

Most of the variation in mountain sucker abundance and biomass was from residual variation (Figure A1). Residual variation represented 60% of the total variation in abundance and 61% of the total variation in biomass. Site-to-site differences (i.e., site variance) accounted for 25 to 30% of the variation in mountain sucker abundance and biomass, respectively. Synchronous variation was 7% of the total variance in abundance, but was negligible for biomass, likely indicating similar reproductive success among sites and similar contributions of large numbers of small fish to the monitored populations. Inter-annual fluctuations in biomass at individual sites accounted for 10% of the total variation. Since the majority of variation in mountain sucker abundance over time was from residual variation, it can probably be reduced. Residual variation results from sampling error, sampling variance, the time of year when populations are sampled, and inter-annual variation in population demographics (spawning, recruitment, etc.). Because capture probabilities were typically high (Appendix B), sampling error was likely a small portion of the residual variation. This suggests that large temporal window for sampling within a year likely resulted in some of this variation. This source of variation could possibly be reduced by sampling mountain sucker populations over a shorter time period during a year. Reduced residual variation would improve trend detection capability.

There was no overall trend in abundance or biomass of mountain sucker at the sites studied (Table A1). The average percent annual change in mountain sucker densities among the 23 sites was 0.13×10^{-6}% (SE = 0.15×10^{-6}; $t_{22} = 0.87$; $P = 0.396$). Average percent annual change in standing stock was 0.47×10^{-7}% (SE = 0.67×10^{-7}; $t_{22} = 0.69$; $P = 0.494$). When trends were evaluated for individual sites, mountain sucker densities increased at two sites and decreased at one ($\alpha = 0.20$). Mountain sucker standing stock declined at one site and increased at three sites. Although there was one instance of local population decline, there was no large-scale trend among all sites included in the analysis.

Statistical power to detect trends in mountain sucker densities increased as the number of sites monitored increased and the number of years monitoring increased (Figure A2). The spatial distribution of abundance for each site was generated from a $\log_e$-normal distribution (mean = 31.1; SD = 27.8). The CV in abundance at a site was simulated from a log-normal distribution (mean = 141.6; SD = 1.4). There was good power ($1-\beta \geq 0.80$) to detect a 2.5% annual decline in mountain sucker density after 10 years when 25 or more sites were monitored at $\alpha = 0.10$. There was good power to detect a 2.5% decline after 10 years when 15 or more sites were monitored and $\alpha = 0.20$. Thus, despite the variability in population abundance observed, prospective power analysis suggested that there was still good statistical power to detect relatively moderate population changes (e.g., 2.5% annual decline) in approximately 10 years with a reasonable amount of certainty.

Table A1. Analysis of short-term trends in mountain sucker abundance and biomass in the Black Hills National Forest, South Dakota and Wyoming. Percent annual change was estimated by regressing loge-abundance or loge-biomass versus year for each stream reach. Forest-wide trends were evaluated by estimating trends for each site, and then averaging trend estimates. An asterisk (*) indicates a trend significantly different from zero using a two-tailed test at $\alpha = 0.20$.

Stream	SiteID	Kg/ha or N/ha	Years	Slope	1 SE	*P*
Annie Creek	ANN02	Kg/ha	5	0.20	0.18	0.343
		N/ha	5	0.17	0.51	0.764
	ANN06	Kg/ha	5	-0.25	0.05	0.014*
		N/ha	5	-0.88	0.17	0.014*
Bear Butte Creek	BBC01	Kg/ha	8	0.05	0.10	0.657
		N/ha	8	0.16	0.31	0.626
	BBC02	Kg/ha	8	-0.12	0.14	0.420
		N/ha	8	-0.07	0.14	0.643
	BBC03	Kg/ha	13	0.17	0.08	0.061*
		N/ha	13	0.30	0.25	0.258
	BBC04	Kg/ha	4	-0.01	0.56	0.992
		N/ha	4	-0.48	1.30	0.748
	BBC05	Kg/ha	11	0.19	0.10	0.099*
		N/ha	11	0.54	0.21	0.029*
	BBC06	Kg/ha	9	0.18	0.09	0.071*
		N/ha	9	0.37	0.287	0.243
	BBC14	Kg/ha	8	0.18	0.21	0.420
		N/ha	8	0.28	0.45	0.553
French Creek	FRC01	Kg/ha	4	0.36	0.34	0.404
		N/ha	4	0.50	0.24	0.174*
Rapid Creek	RAP07	Kg/ha	13	-0.04	0.05	0.446
		N/ha	13	0.01	0.12	0.948
	RAP10	Kg/ha	8	-0.09	0.09	0.365
		N/ha	8	-0.03	0.19	0.872
	RAP18	Kg/ha	8	-0.001	0.04	0.996
		N/ha	8	0.04	0.10	0.670
	RAP22	Kg/ha	7	-0.03	0.03	0.282
		N/ha	7	-0.17	0.16	0.333
	RAP27	Kg/ha	6	0.02	0.04	0.525
		N/ha	6	0.10	0.13	0.460
	RAP35	Kg/ha	4	-0.004	0.01	0.741
		N/ha	4	-0.26	0.70	0.741
Strawberry Creek	STB02	Kg/ha	6	-0.21	0.23	0.427
		N/ha	6	-0.51	0.69	0.495
Whitewood Creek	WWC01	Kg/ha	9	-0.07	0.09	0.481
		N/ha	9	-0.11	0.09	0.256
	WWC08	Kg/ha	8	-0.05	0.14	0.747
		N/ha	8	-0.21	0.33	0.544
	WWC09	Kg/ha	7	-0.19	0.18	0.331
		N/ha	7	-0.17	0.39	0.671
	WWC19	Kg/ha	6	-0.08	0.17	0.673
		N/ha	6	0.41	0.56	0.506
	WWC20	Kg/ha	6	0.07	0.07	0.417
		N/ha	6	0.35	0.36	0.389
	WWC21	Kg/ha	7	-0.01	0.03	0.803
		N/ha	7	-0.05	0.18	0.803
Mean	All	Kg/ha	23	0.47×10^{-7}	0.67×10^{-7}	0.494
		N/ha	23	0.13×10^{-6}	0.15×10^{-6}	0.396

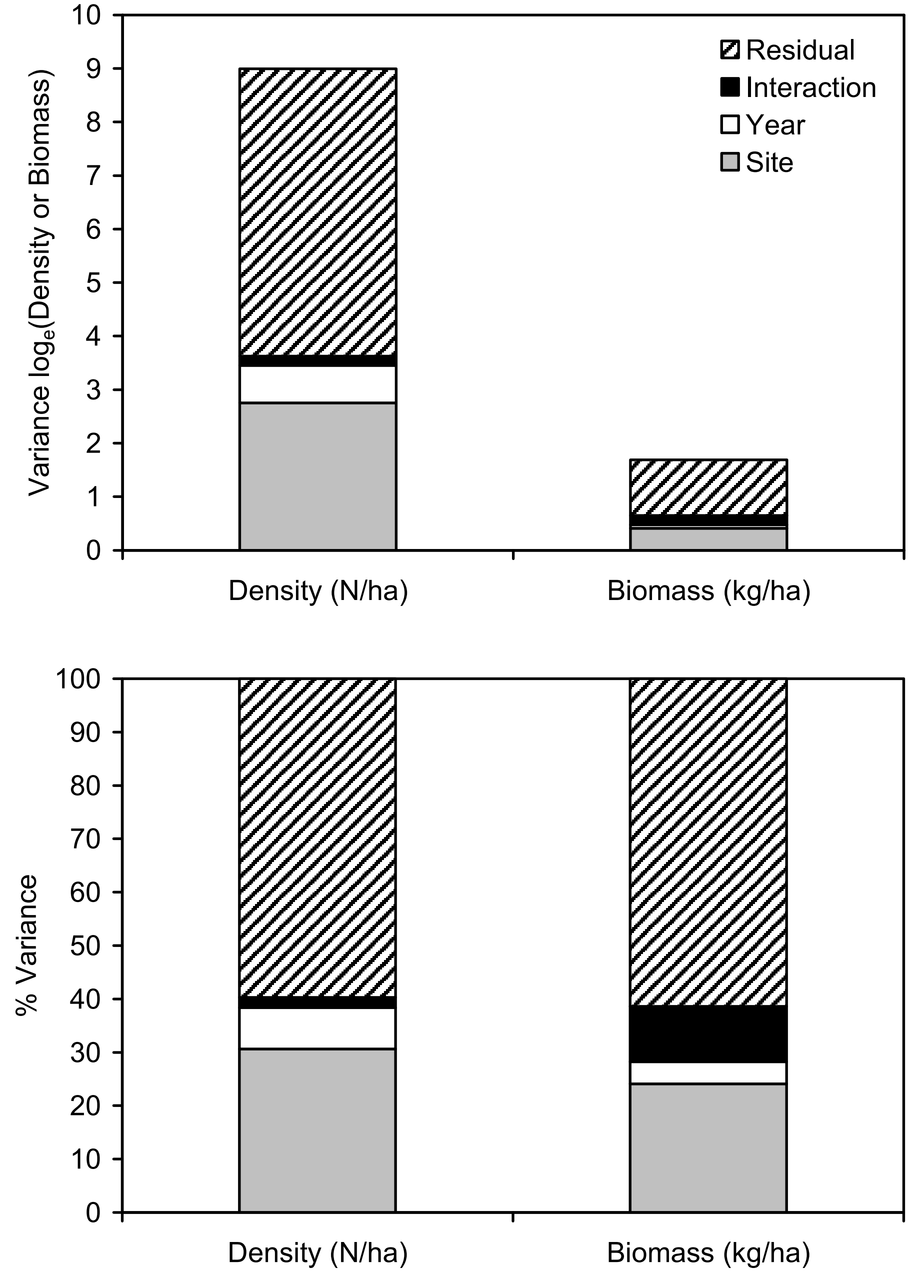


Figure A1. Total variance and percent total variance in mountain sucker density and biomass attributable to site, coherent, interaction, and residual variance, Black Hills National Forest, South Dakota and Wyoming.

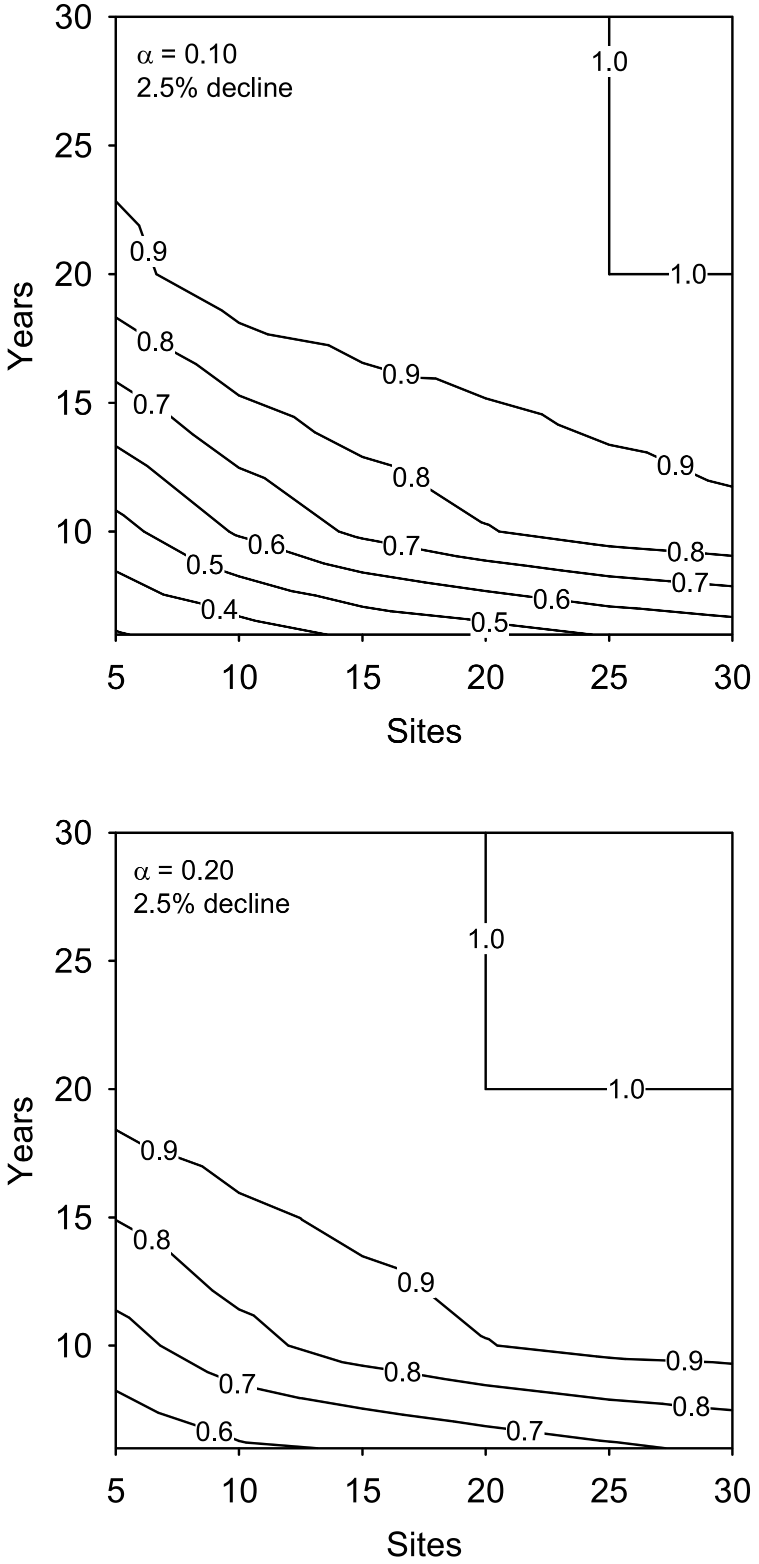


Figure A2. Statistical power to detect a 2.5% annual decline in mountain sucker abundance when the number of sites monitored and years of monitoring varied.

Appendix B. Estimated capture probabilities of mountain sucker when electrofishing in streams in and around the Black Hills National Forest, South Dakota and Wyoming.

Data from stream fish surveys conducted by South Dakota Department of Game, Fish, and Parks on or near the Black Hills National Forest were used to assess efficiency of electrofishing for sampling mountain sucker populations. Fish populations were sampled during surveys using multiple-pass electrofishing. Abundance was estimated using a removal estimator (Zippin 1958). We used data from these fish collections to estimate capture probabilities of mountain sucker. Capture probability for all *n* passes (typically three) was estimated as: $\hat{p}_{npass} = \hat{C} / \hat{N}$, where $\hat{C}$ is the estimated number of mountain sucker collected and $\hat{N}$ is the estimated number of mountain sucker available to be collected within the stream reach during electrofishing. Capture probabilities for one electrofishing pass was done by assuming equal capture probability among samples, and using the relation:

$$\hat{p}_{npass} = 1 - \left(1 - \hat{p}_{1pass}\right)^n$$

where *n* is the number of electrofishing passes, which was typically three, and $\hat{p}_{1pass}$ is the estimated capture probability for one electrofishing pass. Logistic regression was used to determine if 3-pass capture probability was related to stream width (sensu Riley et al. 1993). Model fit was evaluated using a Hosmer-Lemeshow test (Hosmer and Lemeshow 2000).

Capture probabilities were estimated to be very high, with some exceptions. One-pass capture probabilities averaged 0.78 (SE = 0.02), and ranged from 0.07 to 1.00.

three-pass estimates averaged 0.91 (SE = 0.01), and ranged from 0.20 to 1.00. Logistic regression suggested that 3-pass capture probability of mountain sucker decreased with increased stream width ($b_{width} = -0.165$; SE = 0.017); however, the model showed lack of fit ($\chi^2 = 198.8$; df = 8; $P < 0.001$), suggesting that other factors also influence capture probability. Thus, mean stream width should not be used by itself to predict capture probability. Other researchers have shown that capture probability can vary among electrofishing passes and lead to biased abundance and capture probability estimates (Peterson et al. 2004). However, biases are low or absent when capture probabilities are high (Riley and Fausch 1992), such as those we observed for mountain sucker. Thus, the abundance of mountain sucker when made using multiple-pass electrofishing and a removal estimator should be accurate in most instances. Furthermore, mountain sucker presence within a reach in Black Hills streams can often be detected with high probability. The probability of detecting mountain sucker in a reach is dependent on n-pass capture probability and abundance:

$$P(\textit{detecting 1 or more MTS}) = 1 - (1 - p_{npass})^N$$

Where p_{npass} is the probability of capture for each mountain sucker when n electrofishing passes are made, and N = the number of mountain suckers available for capture. Thus, the probability of detection within the sampled stream reach increases as the number of electrofishing passes increases. For example, if five mountain sucker are within a stream reach that is sampled with one electrofishing pass, the average probability of detecting at least one mountain sucker within the reach is: $1 - (1 - 0.78)^5 = 0.999$.

Appendix C. Mountain sucker distribution model, Black Hills National Forest, South Dakota and Wyoming

Stream fishes are often associated with certain habitat characteristics. These stream characteristics can be used to develop logistic regression models that predict the likelihood that a given stream reach will provide habitat suitable for that species and it will occur there (Filipe et al. 2002). We used existing fish survey and habitat data from streams on the Black Hills National Forest to develop a logistic regression model for the mountain sucker. The model can be used to identify stream segments on the forest or within a watershed that have a high probability of having mountain sucker present. This information can be used to determine where to sample within the watersheds selected for monitoring trends in the distribution of mountain sucker across the Forest.

METHODS

Factors influencing mountain sucker occurrence

The occurrence of mountain suckers in the Black Hills National Forest was modeled using data from a 1:24,000 scale stream network and an existing database of fish collections. Each stream segment on the network was attributed with four abiotic predictor variables. Fish collection data were spatially linked to stream segments. Logistic regression was used to model the presence-absence of mountain suckers at each site using the predictor variables. Multiple models that included different combinations of variables were compared using several diagnostic methods to identify the model that best predicted mountain sucker occurrences. The best model was then applied to the entire stream network to predict probability of occurrence for all stream segments on the

Black Hills National Forest. Finally, a variable regarding the abundance of brown trout was added to the best model to evaluate the effects of a potential predator on mountain sucker occurrence.

Stream network. – An existing GIS database of streams on the Black Hills National Forest was used to evaluate the effects of four abiotic predictors of mountain sucker occurrence. The stream network was created by the Black Hills National Forest to be used in forest planning. It originated from 1:24,000 scale topographic maps, and was available in the Universal Transverse Mercator, Zone 13 coordinate system and North American Datum 1983 datum. Streams were divided into segments, often lengths of stream between tributary confluences, that were typically 1 to 10-km in length.
Each segment in the stream network was attributed with information on stream permanence, stream order, elevation, and slope that represent characteristics of streams at the segment scale. The permanence of stream segments was classified as perennial or intermittent (perennial = 1, intermittent = 0) based on original topographic map classifications, but classifications were updated by forest biologists using field data. Stream permanence can be important to fishes that are sensitive to streamflow patterns (Travnichek et al. 1995). Stream order is a measure of stream size ranging from 1st order for the smallest streams to higher orders for larger streams. The stream order of each segment was determined using the Strahler (1957) method, whereby stream segments without tributaries are 1st order, segments below the confluence of two 1st order segments are 2nd order, and so on where segments below the confluence of segments of the same order are assigned the next higher order. Streamflow, temperature, physical habitat and energy sources often change with stream size and influence the distribution of fishes (Vannote et al. 1980). Stream slope (m/km) was computed as the change in elevation

over each stream segment divided by segment length. Stream slope is often correlated with physical habitat characteristics that are important to stream fishes, and can be used as surrogate for instream habitat conditions (Isaak and Hubert 2000). Elevations (m) of segment nodes were obtained from a 10-m digital elevation model, and were averaged for segment elevation. Elevation is often used as a surrogate for stream temperatures that influence fish distributions (Rahel and Nibbelink 1999).

Fish collection data. – Existing fish collection data were used to determine the presence of mountain suckers in streams of the Black Hills National Forest. South Dakota Department of Game, Fish, and Parks sampled fishes at 289 stream sites on the Black Hills National Forest from 1988 to 2004. They estimated abundance of fishes within a 100-m stream reach using a 3-pass removal estimate (Zippin 1958). Three-pass capture probabilities for mountain suckers were estimated for a subset of these data and they ranged from 0.20 to 1.00 with a median of 1.00 (mean = 0.91). Because capture probability (q) and the number of individuals present (n) determine detection probability $d = 1 - (1 - q)^n$ (Bayley and Peterson 2001), mountain suckers were very likely to be detected during electrofishing even if only one individual was present in the reach. If a site was sampled during multiple years, only data from the most recent year were used. The spatial location of each site was represented in a GIS database, and ArcGIS 9.1 GIS software (ESRI, Inc., Redlands, California) was used to spatially link sampling sites to the stream network.

Modeling presence-absence. – Multiple logistic regression was used to model the effects of the abiotic predictor variables on mountain sucker presence at a stream site. Logistic regression is similar to linear regression except that it predicts a binary response (0 = absence, 1 = presence) from one or more predictor variables (Hosmer and

Lemeshow 2000). Logistic regression was used to model the presence-absence of mountain suckers because it has been shown to be as accurate or more accurate in predicting the presence of stream fishes when compared to other modeling techniques that can predict a binary response (Steen et al. 2006).

Several logistic regression models were constructed and evaluated to determine which model was the most parsimonious model. First, all four predictor variables and first order interactions between stream order, segment slope, and elevation were included in a global model. This global model was the largest model (contained the most predictors), and, hence, would fit the data best. To ensure that this largest model fit the data, lack-of-fit of the global model was assessed using a Hosmer-Lemeshow test (Hosmer and Lemeshow 2000). Discrimination ability of the global model was evaluated using two methods: a receiver operating characteristic (ROC) curve and k-fold cross validation. The ROC curve is a plot of sensitivity versus 1-specificity over the entire range of possible probabilities (0 to 1) used to classify an observation as present or absent. The area under the curve provides a measure of discrimination ability ranging from 0.5 for no discrimination to 1.0 for complete discrimination (Hosmer and Lemeshow 2000). Independent model validation was done using k-fold cross validation (Boyce et al. 2002). The data set was partitioned into k = five sets, and the global model was fit to 80% of the dataset and the remaining 20% was used for cross validation. The cross-validated dataset was partitioned into five bins, and Spearman rank correlation was used to compare the association between the median [independently] predicted probability of occurrence and the percent of observations with mountain suckers present among bins. This process was repeated 5 times for each 20% of the original dataset, and correlations were averaged to test for model fit. An r^2 measure of fit was not used because they are not recommended (Hosmer and Lemeshow 2000), and a 2×2 classification table was not used because they rely on an arbitrary threshold probability to classify presence and can be biased when species occur infrequently (Pearce and Ferrier 2000; Olden et al. 2002). Whether or not a stream segment was perennial was assumed to influence mountain sucker presence, as it would for most fish species, and the stream permanence predictor variable was included in all candidate models to estimate effect size (Johnson 1999). The set of candidate models consisted of the global model and models with all combinations of variables in the global model (with stream permanence always included) and first order interactions. All models were evaluated for plausibility (Burnham and Anderson 2002). Akaike's Information Criterion corrected for small sample bias (AIC_c) was used to quantify parsimony in each model, that is, which model explained the most variation in the data with the fewest number of parameters. Akaike weights (w_i) were computed to determine the probability that a given model is the best model (Burnham and Anderson 2002). Model averaging was conducted if needed using models within 4 AIC_c units of the best model and w_i were used as model weights. Parameters not included in a specific model were given a value of zero for that model during averaging (Burnham and Anderson 2002). All statistical analyses were done using SAS Version 9.1 statistical software (SAS Institute, Inc., Cary, North Carolina).

Mapping occurrence probabilities

The model that best predicted the probability of mountain sucker occurrence was used to predict probabilities of occurrence for each segment in the stream network on the Black Hills National Forest. Since each stream segment was attributed with the predictor variables evaluated in logistic regression models, the attributes of each stream segment could be included in the model to predict occurrence probabilities that ranged continuously from 0 to 1 for each segment. The predicted occurrence probability for each segment was placed in a new field in the attribute table of the GIS database for the stream network. This allowed occurrence probabilities to become spatially explicit and predicted across the forest. Spatially explicit probabilities of occurrence were computed and displayed using ArcGIS 9.1 software (ESRI, Inc., Redlands, California).

Effect of brown trout on mountain sucker occurrence

The density of large brown trout (≥20-cm) was also evaluated for an effect on mountain sucker occurrence. The size threshold was identified in the South Dakota Game, Fish, and Parks' database and represents trout likely to be predatory on the mountain sucker. This biotic effect was modeled after modeling the effects of abiotic factors because brown trout densities were not known for much of the stream network. If brown trout density was evaluated in the initial models, it would have prohibited modeling mountain sucker occurrence for the majority of streams on the forest where no data on brown trout density were available. After the final model or best set of candidate models was selected describing how abiotic factors affected the probability of mountain sucker occurrence, then a brown trout density variable was added. Models with and without a brown trout density variable were compared using AIC_c as described above. If brown trout density had a plausible effect, then its coefficient was estimated for the best model or by using model averaging.

RESULTS

Factors influencing mountain sucker occurrence

Stream network. – The network of streams within the Black Hills National Forest contained 9374 stream segments with 7498 segments (6643 of 88132 km) representing intermittent streams that were typically small. Stream orders ranged from 1 to 7, with 4713 segments being 1st order, 2341 2nd order, and the remaining 3rd order or higher. Elevations ranged from 923 to 2108 m, and averaged 1550 m. Segment slopes ranged from 0 to greater than 600 m/km, with an average of 44 m/km.

Fish collection data. – Mountain suckers were present at 49 of the 289 sites that were sampled for fishes on the Black Hills National Forest (Figure C1). Mountain suckers were never collected within first-order streams, and were collected in only 5 of 69 reaches that were classified as intermittent (Table C1). They were collected in reaches at all but the highest slope values sampled, and were collected across a wide range of elevations.

Modeling presence-absence. – The occurrence of mountain suckers at a site was influenced by the four abiotic variables in complex ways. There were no strong correlations indicating redundancy among the three continuous variables and all were included in the global model ($|r|_{max} = 0.59$). The global model did not show lack of fit (Hosmer-Lemeshow: $\chi^2 = 5.56$, df = 8, $P = 0.697$) and had an ROC = 0.76. An ROC between 0.7 and 0.8 indicates that the model had an acceptable ability to discriminate between sites with and without mountain suckers (Hosmer and Lemeshow 2000). The k-fold cross validation resulted in a mean Spearman correlation among 5 bins of $r_s = 0.955$, indicating very good fit of models to the data (Boyce et al. 2002). Model selection criteria showed that of the 40 candidate models examined, the model with stream permanence, stream slope, stream order, elevation, and first order interactions among slope, stream order, and elevation had the minimum AIC_c and was the most plausible model (Table C2). No other model had $\Delta AIC_c < 4$. Hence, model averaging was not done and only the best model was used. The best model showed a good ability to discriminate between sites where mountain suckers were present versus absent (ROC = 0.76) and based on the Akaike weights had a probability of 0.85 of being the best model. Parameter estimates suggested that mountain suckers were more likely to be present in perennial streams, but the effects of stream slope, elevation, and stream order were complex and depended on the values of other variables (Table C3; Figure C2). For example, mountain suckers were more likely to be present in large streams when gradient is high but small streams when gradient is low (Figure C2C). Mountain suckers were more likely to be present in large streams at high elevations but small streams at low elevations (Figure C2D). They were also more likely to be present in high gradient streams at high elevations and low gradient streams at low elevations (Figure C2E).

Mapping occurrence probabilities

The best model (i.e., model with minimum AIC_c) based on only habitat data was used to estimate a probability of mountain sucker occurrence for each individual segment in the stream network for the Black Hills National Forest. The model predicted that the majority of streams had a low probability of having mountain suckers present (Figure C3). In fact, 76% of the 8132-km of streams (perennial and intermittent) on the Forest had a probability between 0 and 0.05 of having mountain suckers present, with many km of stream having a probability near zero. By contrast, only 2% of the stream km had a high probability (>0.5) of mountain sucker occurrence. These stream segments were distributed throughout the Forest, with a small concentration in the south (Figure C4).

Effect of brown trout on mountain sucker occurrence

Brown trout were collected at 103 of 289 sites in the South Dakota Department of Game, Fish and Parks database, and densities ranged from 9 to 3587 / ha. Of the 49 sites were mountain suckers were present, brown trout were present at 21 of those sites. The model that included brown trout density was more plausible than the best model consisting of only abiotic characteristics of streams (Table C2). However, there was still a probability of 0.29 that the model without a brown trout variable was the best model. When model parameters were averaged across the two models using Akaike weights (w_i), the estimated effect of large brown trout on mountain sucker presence in streams was negative (Table C3).

Conclusions

A logistic regression model based on several habitat features does a good job of predicting the presence of mountain sucker at stream sites in the Black Hills National Forest. This model could be used to identify stream reaches within a watershed that have the highest probability of containing mountain sucker. These reaches could then be sampled as indicated in the protocol for monitoring trends in the distribution of mountain sucker across the Forest.

Table C1. Summary of stream characteristics where mountain sucker were present versus absent in stream sites of the Black Hills National Forest, South Dakota and Wyoming.

Variable	Mountain sucker	n	Mean	SD	Range
Perennial	Present	44			
	Absent	176			
Non-perennial	Present	5			
	Absent	64			
Slope (m/km)	Present	49	15.8	11.9	2.6 – 63.0
	Absent	240	27.5	22.6	0.2 – 124.2
Stream order	Present	49	3	1	2 - 5
	Absent	240	3	1	1 - 5
Elevation (m)	Present	49	1521	149	1189 – 1883
	Absent	240	1552	188	975 – 1952
Brown trout (n/ha)	Present	49	143	283	0 – 1388
	Absent	240	213	484	0 – 3587

Table C2. Linear predictor functions of logistic regression models used to model mountain sucker probability of presence in streams of the Black Hills National Forest, South Dakota and Wyoming. Only models within 10 ΔAICc units of the best model are presented. The effect of brown trout density on mountain sucker presence was evaluated by adding it to the most plausible model based solely on stream characteristic effects.

Model	log(L)	AIC_c	ΔAIC_c	w_i
Stream characteristic effects				
Perennial+Slope+Order+Elevation+S×O+S×E+O×E	-110.34	237.20	0.00	0.851
Perennial+Slope+Order+Elevation+P×S+P×O+P×E+S×O+S×E+O×E	-109.27	241.49	4.28	0.100
Perennial+Slope+Order+Elevation+S×E+O×E	-114.95	244.30	7.10	0.024
Perennial+Slope+Order+Elevation+S×O+S×E	-115.78	245.95	8.75	0.010
Brown trout effect on mountain sucker occurrence				
Perennial+Slope+Order+Elevation+S×O+S×E+O×E+BrownTrout	-108.39	235.43	0.00	0.709
Perennial+Slope+Order+Elevation+S×O+S×E+O×E	-110.34	237.20	1.78	0.291

Table C3. Parameter estimates (b_i), standard errors (SE), and 95% confidence intervals for logistic regression models, with and without a brown trout effect, predicting probability of mountain sucker presence in streams of the Black Hills National Forest, South Dakota and Wyoming. The brown trout excluded model is the best model from Table C2 based on only physical stream characteristics. Parameter estimates for the brown trout included model are an average from those of the best model without brown trout and the same model with brown trout in Table C2.

	Brown trout excluded			Brown trout included		
Variable	b_i	SE	95% CI	b_i	SE	95% CI
Intercept	41.9968	11.4553	19.086, 64.907	41.2519	11.2937	18.665, 63.839
Perennial (Yes = 1; No = 0)	0.4097	0.6063	-0.803, 1.622	0.4908	0.6100	-0.729, 1.711
Slope (m/km)	-1.1917	0.3036	-1.799, -0.585	-1.1924	0.3058	-1.80, -0.581
Stream order (Strahler)	-7.5843	2.3433	-12.271, -2.898	-7.4615	2.3064	-12.074, -2.849
Elevation (m)	-0.0255	0.0072	-0.040, -0.011	-0.0252	0.0070	-0.039, -0.011
Slope×Stream order	0.0592	0.0218	0.016, 0.103	0.0603	0.0213	0.018, 0.103
Slope×Elevation	0.0006	0.0002	0.0002, 0.0010	0.0006	0.0002	0.0002, 0.0010
Stream order×Elevation	0.0042	0.0015	0.001, 0.007	0.0042	0.0015	0.001, 0.007
Brown trout (n/ha)				-0.0007	0.0006	-0.0019, 0.0005

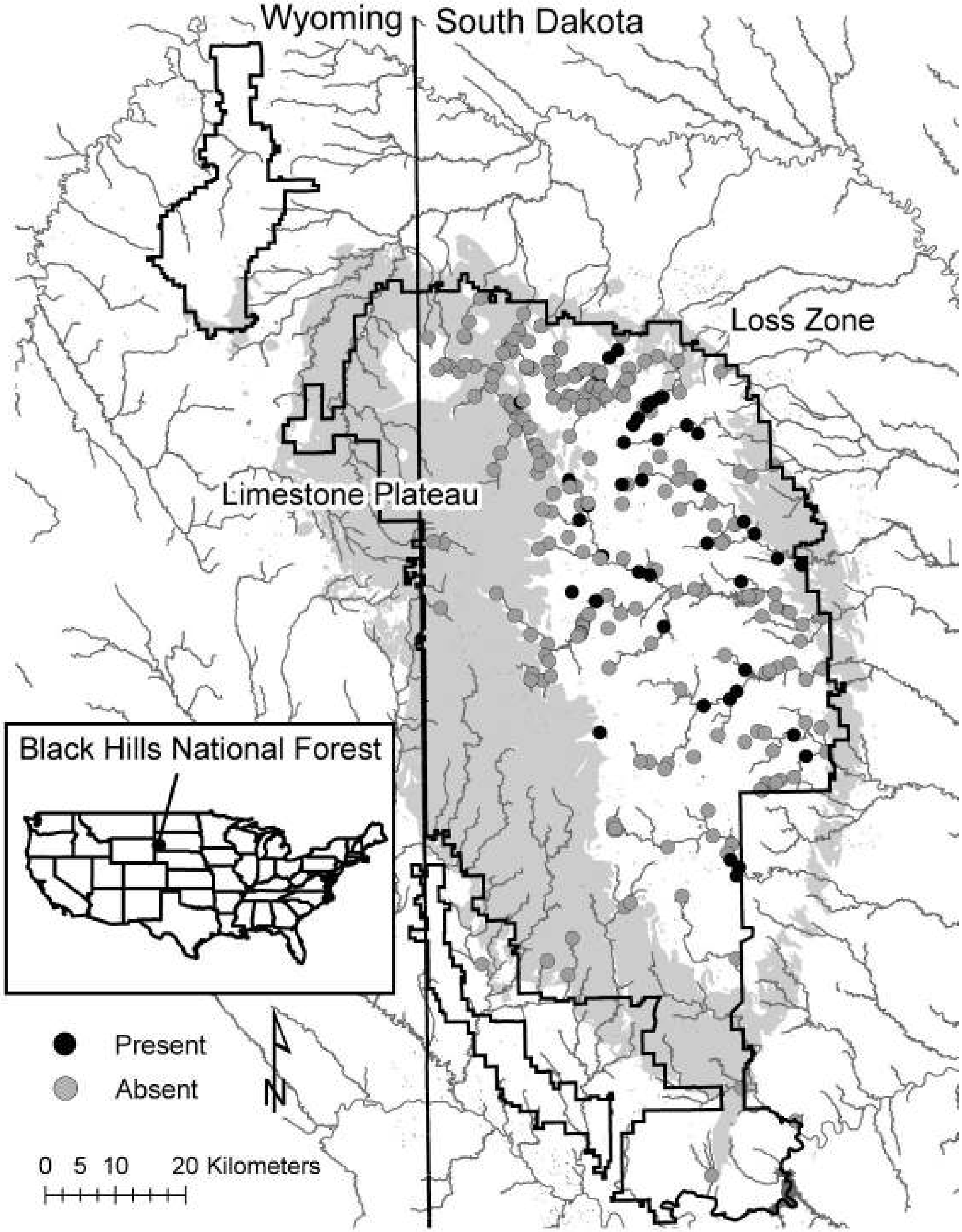


Figure C1. Fish collection sites where mountain suckers were present and absent when sampled from 1988 to 2004 on streams in the Black Hills National Forest, South Dakota and Wyoming. Only 3rd order and larger streams are shown. Madison Limestone, Minnelusa, and Minnekahta geologic formations are shown in grey. They represent zones where streams are often intermittent at high elevations in the western Limestone Plateau region or at low elevations in the Loss Zone in the north and east as streams flow off of the Black Hills.

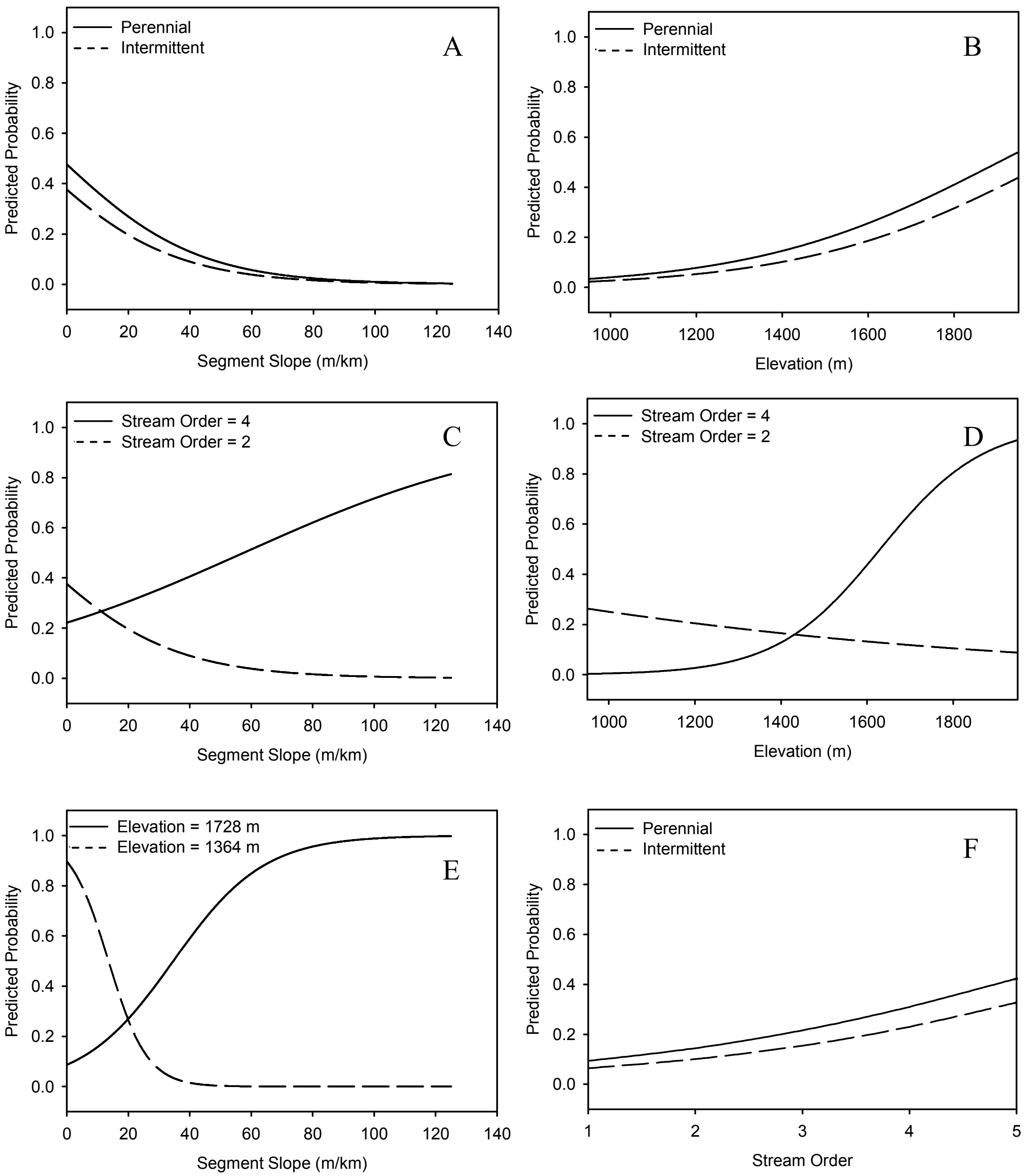


Figure C2. Predicted probability of occurrence for mountain suckers at stream sites differing in stream permanence, stream slope, stream order, and elevation in the Black Hills National Forest, South Dakota and Wyoming. Probabilities for variables that interacted with other variables (stream order, slope, elevation) are predicted at the mean ± 1 SD values of those variables to show their interaction; all remaining variables were held at their mean value.

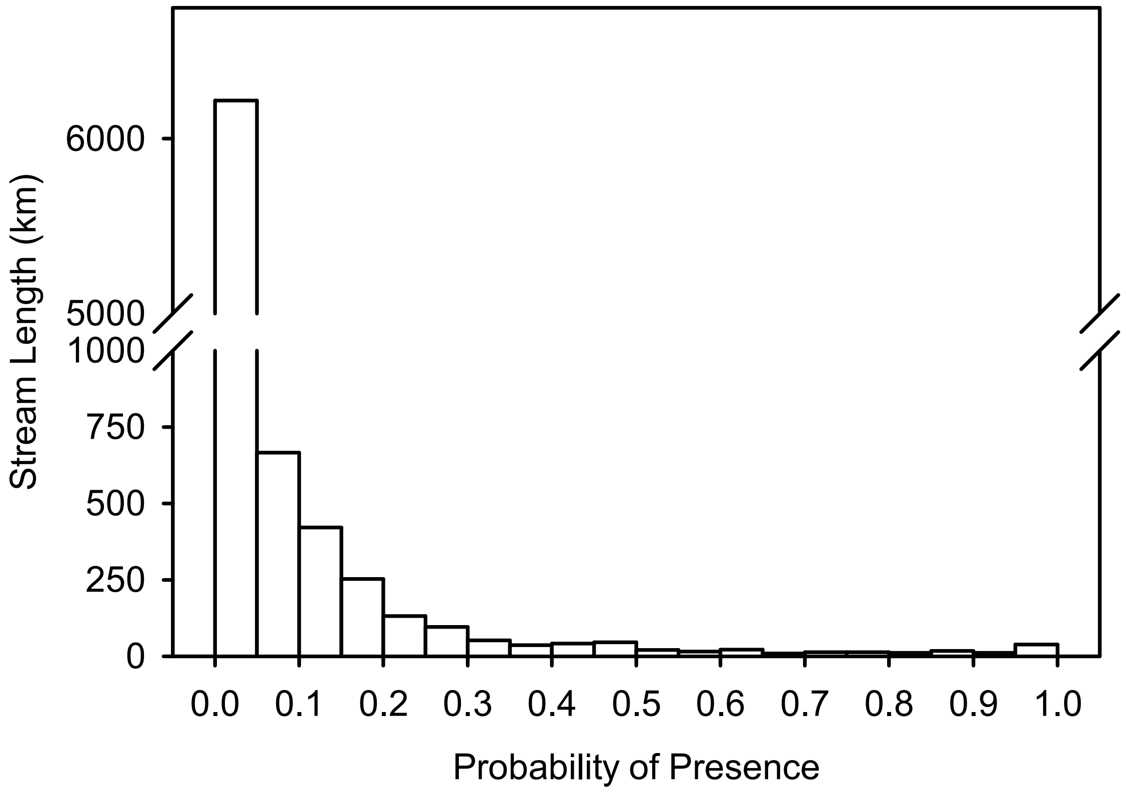


Figure C3. Total stream length in the Black Hills National Forest in relation to the predicted probability of mountain sucker presence.

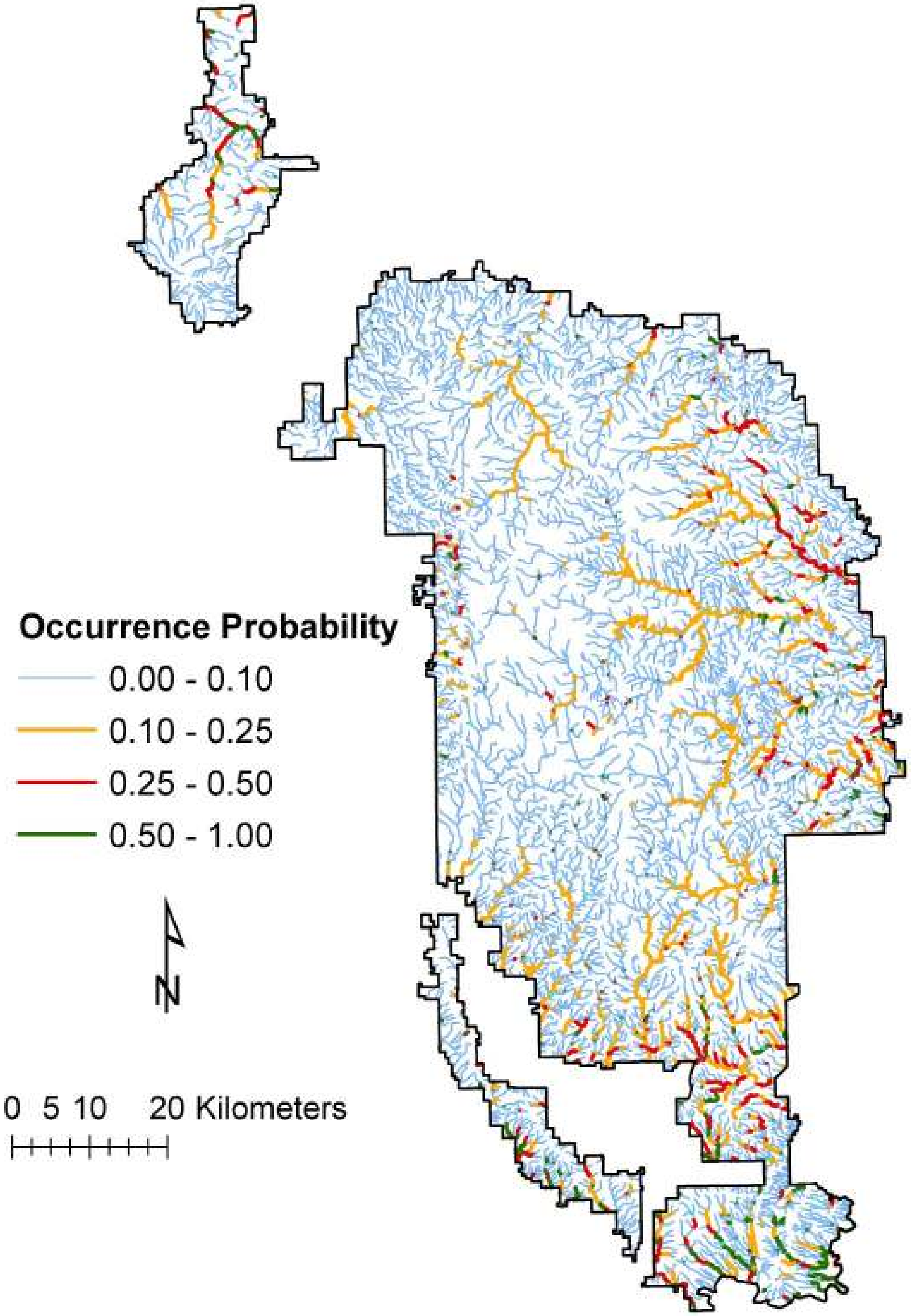


Figure C4. Predicted probabilities of mountain sucker presence for stream segments on the Black Hills National Forest, South Dakota and Wyoming.

Appendix D. Wyoming Game and Fish Department and South Dakota Department of Game, Fish, and Parks electrofishing data sheets.

Date___/___/___

STREAM ELECTROFISHING DATA

Page_____of_____

Stream ______________________ Location ______________________________________ Section Length __________

Avg. Width __________Mark ______________Pass __________Equipment ______________________________________

Water Temp.__________ Water Cond.__________ VVP Settings: Volts__________ PPS__________ PW__________ Amps__________

Other ____

	Spcs	Length	Weight	Mark	Comments	Spcs	Length	Weight	Mark	Comments
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23										
24										
25										

	Spcs	Length	Weight	Mark	Comments	Spcs	Length	Weight	Mark	Comments
26										
27										
28										
29										
30										
31										
32										
33										
34										
35										
36										
37										
38										
39										
40										
41										
42										
43										
44										
45										
46										
47										
48										
49										
50										
51										
52										
53										
54										
55										

S. D. GAME FISH AND PARKS - STREAM SURVEY FIELD DATA SHEET

Stream Name: ______________________ Page 1 of ____

Site Number: ☐☐

DATE (d d m m m y y) ☐☐☐☐☐☐☐

Site Description: ______________________

Site Length (meters): ☐☐☐ S ☐☐ R ☐☐☐ T ☐☐☐

pH: ☐.☐

Cond. (umhos/cm): ☐☐☐☐

Temp.(C) air: ☐☐.☐

Water: ☐☐.☐

Dist. below top net (meters)	Stream Widths (meters)	Dist. below top net (meters)	Stream Widths (meters)
0	☐☐.☐	5 0	☐☐.☐
1 0	☐☐.☐	6 0	☐☐.☐
2 0	☐☐.☐	7 0	☐☐.☐
3 0	☐☐.☐	8 0	☐☐.☐
4 0	☐☐.☐	9 0	☐☐.☐
		1 0 0	☐☐.☐

Smith-Roots

Mode: ☐☐☐

Volts: ☐☐☐

Personnel:

#1	☐☐☐	#2	☐☐☐	#3	☐☐☐	#4	☐☐☐
#5	☐☐☐	#6	☐☐☐	#7	☐☐☐	#8	☐☐☐
Data	☐☐☐	Scales	☐☐☐	Lengths	☐☐☐	Weights	☐☐☐

	Pass #1	Pass #2	Pass #3	Pass #4	Pass #5
Start time: (hhmm)	☐☐☐☐	☐☐☐☐	☐☐☐☐	☐☐☐☐	☐☐☐☐
End time: (hhmm)	☐☐☐☐	☐☐☐☐	☐☐☐☐	☐☐☐☐	☐☐☐☐
Smith-Root (seconds)	☐☐☐☐	☐☐☐☐	☐☐☐☐	☐☐☐☐	☐☐☐☐
Shocker #1	☐☐☐	☐☐☐	☐☐☐	☐☐☐	☐☐☐
Smith-Root (seconds)	☐☐☐☐	☐☐☐☐	☐☐☐☐	☐☐☐☐	☐☐☐☐
Shocker #2	☐☐☐	☐☐☐	☐☐☐	☐☐☐	☐☐☐
Smith-Root (seconds)	☐☐☐☐	☐☐☐☐	☐☐☐☐	☐☐☐☐	☐☐☐☐
Shocker #3	☐☐☐	☐☐☐	☐☐☐	☐☐☐	☐☐☐

Rare Species Observed (i.e. American Dipper) ______________________

____

____

Comments: ______________________

____

____

Page 2 of ______

Bulk Weights - (Record #5)

	(m m)		(m m)	Pass#	Species	Total Number	Total Weight
Size Range:		to					
Size Range:		to					
Size Range:		to					
Size Range:		to					
Size Range:		to					
Size Range:		to					
Size Range:		to					
Size Range:		to					
Size Range:		to					
Size Range:		to					

Digital Photos - Description
Top Blocking Net Looking Upstream____________________
Top Blocking Net Looking Downstream __________________
Bottom Blocking Net Looking Upstream__________________
Bottom Blocking Net Looking Downstream _______________

Video Camera

Tape #:	
Begin:	
End:	

Barge Shocker:
Range (H/L): ☐ Percent: ☐☐☐ Amps: ☐. ☐ Pulse: ☐☐☐ ☐☐

Pass	Start time (h h m m)	End time (h h m m)	Duration (seconds)	Anode #1	Anode #2	Anode #3
1						
2						
3						
4						

DATA ENTRY - RECORD 2

	(d d m m m y y)	Personnel
Data Entry		
Verification:		

DATA ENTRY - RECORD 3

	(d d m m m y y)	Personnel
Data Entry		
Verification:		

DATA ENTRY - RECORD 4

	(d d m m m y y)	Personnel
Data Entry		
Verification:		

DATA ENTRY - RECORD 5

	(d d m m m y y)	Personnel
Data Entry		
Verification:		

Field Q.C. by:______________

Batch Number: ☐☐☐☐

SOUTH DAKOTA GAME FISH AND PARKS   3305 WEST SOUTH STREET   RAPID CITY, SD 57702

DATE

dd-mmm-yy

Stream Name ____________________

Page _____ **of**_____

Site Number _____

example 0 2 M A Y 9 2

Fish ID #	Pass #	Species Code	Total Length (mm)	Weight (grams)	Sca.	Mor.	Sex	Comments	Fish ID #	Pass #	Species Code	Total Length (mm)	Weight (grams)	Sca.	Mor.	Sex	Comments
1									51								
2									52								
3									53								
4									54								
5									55								
6									56								
7									57								
8									58								
9									59								
10									60								
11									61								
12									62								
13									63								
14									64								
15									65								
16									66								
17									67								
18									68								
19									69								
20									70								
21									71								
22									72								
23									73								
24									74								
25									75								
26									76								
27									77								
28									78								
29									79								
30									80								
31									81								
32									82								
33									83								
34									84								
35									85								
36									86								
37									87								
38									88								
39									89								
40									90								
41									91								
42									92								
43									93								
44									94								
45									95								
46									96								
47									97								
48									98								
49									99								
50									00								