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Distribution, Density, Movement, and Support for Management of Mountain Sucker, *Pantosteus jordani*, in the Black Hills of South Dakota

Seth J. Fopma
South Dakota State University

DISTRIBUTION, DENSITY, MOVEMENT, AND SUPPORT FOR MANAGEMENT OF MOUNTAIN SUCKER, *PANTOSTEUS JORDANI*, IN THE BLACK HILLS OF SOUTH DAKOTA

BY

SETH J. FOPMA

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DISSERTATION ACCEPTANCE PAGE

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This dissertation is approved as a creditable and independent investigation by a candidate for the Doctor of Philosophy degree and is acceptable for meeting the dissertation requirements for this degree. Acceptance of this does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Brian Graeb
Advisor Date

Michele R. Dudash
Department Head Date

Dean, Graduate School Date

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

DISTRIBUTION, DENSITY, MOVEMENT, AND SUPPORT FOR MANAGEMENT OF MOUNTAIN SUCKER, *PANTOSTEUS JORDANI*, IN THE BLACK HILLS OF SOUTH DAKOTA

SETH J. FOPMA

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Mountain Sucker, *Pantosteus jordani*, is a cold-water species native to the Intermountain West. Fringe populations of Mountain Sucker have experienced declines in recent decades. The population of Mountain Sucker found in the Black Hills of South Dakota represents the eastern fringe of the species' native range. Recognized as both an indicator of biologic health and as a species of greatest conservation need in South Dakota, recent studies have suggested significant declines in both distribution and abundance. Despite the recent study of Mountain Sucker in the region, increased understanding of Mountain Sucker ecology is needed to effectively manage for the conservation of this species. First, I assessed public perceptions towards the management of non-game, native species in the region. Traditional stream management has focused on the proliferation of non-native salmonids due to their recreational and economic value. Public support for management was generally positive for residents of the Black Hills region. Next, I assessed the general movements of Mountain Sucker. General movements were small, indicating high-sight fidelity and limited potential for recolonization of streams and locations where they have been extirpated. Third, we examined segment-scale habitat variable to predict distribution of Mountain Sucker throughout the Black

Hills stream network in South Dakota. Previous work identified the importance of stream permanency in influencing Mountain Sucker occurrence, our results indicated that Mountains Sucker distributions were primarily impacted by mean August stream temperatures at the segment scale. We assessed the current distribution of Mountain Sucker in the Black Hills of South Dakota for comparison with the findings of the most recent research. Mountain Sucker were found in more drainages and at more locations than in the previous study, likely a result of increased detection probabilities associated with more intensive survey designs and repeated site visits. Finally, we assessed 25-year trends in Mountain Sucker density in historically sampled locations. General trends in density were negative; however, significant trends were only observed in three locations. Mountain Sucker appear to have been extirpated from three streams since the most resent assessment. Several sampling locations included high densities of Mountain Sucker that could serve as source populations for restoration efforts via translocation. Overall, this research provides insight into the status of Mountain Sucker in the Black Hills of South Dakota, and the level of public support of active management of this regionally imperiled species. Managers can use this information to guide potential conservation efforts, such as translocations.

CHAPTER ONE: INTRODUCTION

North American freshwater ecosystems are home to the greatest freshwater biodiversity on earth (Abble et al. 2000). Freshwater habitats are one of the most endangered ecosystems in the world (Leidy and Moyle 1998). Due to a variety of anthropogenically driven changes, freshwater organisms are now at increased threat for imperilment. Alterations in lotic connectivity, habitat, hydrologic patterns, aquatic temperatures, and local species assemblages can all negatively impact aquatic biodiversity and health (Olden and Poff 2005, Dudgeon et al. 2006, Helfman 2007). The cumulative impacts of these threats have led to freshwater fish being recognized as one of the most imperiled vertebrate groups worldwide (Ricciardi and Rasmussen 1999). Monitoring changes in aquatic community structure can provide insight into overall ecosystem health (Leidy and Moyle 1998). The loss of biodiversity in North American freshwater ecosystems also threatens their ecological services, economic values, and aesthetic worth (Angermeier and Winston 1999, Bertrand and Gido 2007, Gido et al. 2010).

Conservation ethics dictate that managers consider mechanisms that aid in the conservation of biodiversity (Leopold 1966). The historic prioritization of species-based management resulted in the delineation of “game” and “non-game” species (Leopold 1986). Fish that provide obvious recreational and economic value to society are typically considered to be game fish while fish with unknown societal value are typically considered to be non-game species (Cooke et al. 2012). Freshwater fisheries management has traditionally focused on game species management, occasionally to the detriment of co-occurring non-game species (Clarkson et al. 2005). Recent trends in societal values following the establishment of the Endangered Species Act suggest increasing public support for holistic, conservation-based management emphasizing the role of non-game species as vital components of functioning ecosystems (Beamesderfer 2000, Tyus and Saunders 2000, Manfredo et al. 2003, Clarkson et al. 2005, Manfredo et al. 2009, Teel and Manfredo 2010, Verbrugge et al. 2013, Jacobs et al. 2014).

The Black Hills are a dome shaped uprising located in the Middle Rockies Ecoregion (Level III) and are characterized by dense Ponderosa Pine (*Pinus ponderosa)* stands (Omernik 1987). Considered to be an island in the prairie, the heavily forested Black Hills of South Dakota and Wyoming are surrounded by short and mid-grass prairie (Berry et al. 2007). The Black Hills (100 km N-S, 50 km E-W) contain numerous mountain-fed perennial streams of variable morphology (Schultz et al. 2015). Streams in the Black Hills generally originate from the center as water pushed up through the Precambrian, metamorphic, and intrusive (granite and slate) rocks that make up the center of the dome (DeWitt et al. 1989). The streams then flow outward across an area of Cretaceous, sedimentary (limestone) rock as they descend in elevation towards the prairie. The porous nature of the limestone allows water to flow through them leaving a dry surface above ground, generally referred to as the “loss zone”. In the western portion of the Black Hills this limestone ring is wider serving as a groundwater recharge zone for streams that originate in the center of the Black Hills (Williamson and Carter 2001). The loss zone represents a natural fragmentation of many streams originating in the center of the Black Hills effectively isolating fish populations within drainages. During periods of high runoff water is capable of surficial crossing the loss zone, temporarily restoring connectivity between drainages. Several streams maintain sufficient flow through the loss zone to maintain connectivity year-round.

Changes in land use, mining activities and the fragmentation of streams due to the construction of civil and municipal structures have threatened stream-dwelling organisms throughout the Black Hills (Berry et al. 2007). Additionally local populations of stream dwelling organisms are often isolated between watersheds due to the loss zone and the thermal constrains associated with the intermediate habitats connecting drainages and interspecific interactions with nonnative species (Williamson and Carter 2001, Isaak et al. 2003, Belica and Nibbelink 2006, Dauwalter and Rahel 2008, Schultz et al. 2015).

Mountain Sucker, *Pantosteus jordani*, range extends west of the Black Hills to California, north to British Columbia (Canada) and south to Utah (McPhail 2007, Unmack et al. 2014). Mountain Sucker is listed as secure throughout its range (NatureServe 2019), but recent studies have indicated that localized populations have been in decline (Moyle and Vondracek 1985, Decker 1989, Decker and Erman 1992, COSEWIC 2010, Schultz and Bertrand 2012, Boguski and Watkinson 2013). Mountain Sucker has been identified as an indicator species of biologic health in the Black Hills National Forest of South Dakota and Wyoming (SAIC 2005). It has also been identified as a species of greatest conservation need in South Dakota (SDGFP 2014). Mountain Sucker are part of the non-piscivorous assemblage that originally characterized the Black Hills streams (Berry et al. 2007). Although Mountain Sucker co-occur with natural predators across much of its range, the trout assemblage that characterizes the Black Hills stream fish assemblage today is not native to the region.

A benthic fish, Mountain Sucker can be identified by its small body, cylindrical shape, subterminal and large, fleshy-lipped mouth (Scott and Crossman, 1998). Several morphological characteristics serve to differentiate Mountain Sucker from similar members of the Catostomid family including a round, fleshy snout, lips that are wider than the head itself, and a papillate, cartilaginous ridge located on the lower jaw (Smith 1966). Typical coloration of Mountain Sucker includes an olive green to brown dorsal surface which yields to a pale-yellow ventral surface (Nelson and Paetz 1992). The dorsal surface may include saddle-like, dark blotches. Additionally, both male and female Mountain Sucker develop secondary sexual characteristics during the breeding season. These characteristics include an orange lateral stripe that is more prominent in males, similarly both sexes develop more colored fins and nuptial tubercles which are again more distinct in males (Hauser 1969, Scott and Crossman 1973).

Hauser (1969) reported that Mountain Sucker diets are primarily composed of algae. Carl et al. (1967) suggest that the cartilaginous ridge located on the lower jaw is specialized to scrape periphyton from rocks. Smith (1966) hypothesized that while aquatic invertebrates do make up a significant portion of diets their uptake is likely incidental. Wydoski and Wydoski (2002) suggested that their unique diet allows them to be an important link between primary producers and higher-level consumers.

Mountain Sucker found within South Dakota are considered to be completely isolated from conspecific populations (Bertrand et al. 2016). Historically, Mountain Sucker were widely distributed throughout the complex, cold-water, stream network found throughout the Black Hills region (Bailey and Allum 1962). Segment and local scale habitat factors have been related to Mountain Sucker occurrence in the region. Dauwalter and Rahel (2008) found that stream permanence, slope, order, and elevation interacted to influence occurrence at the segment scale. At the local scale Schultz et al. (2015) observed the occurrence of Mountain Sucker to be explained primarily by substrate size, vegetation coverage, and periphyton coverage. Both authors also observed a negative influence of Brown Trout *Salmo trutta* on the occurrence of Mountain Sucker.

Isaak et al. (2003) assessed Mountain Sucker trends at the turn of the century concluding that there was insufficient evidence to suggest a decline in Mountain Sucker distribution and abundance in the region. More recent assessments indicated significant declines in both distribution and abundance of Mountain Sucker in the Black Hills of South Dakota (Schultz and Bertrand 2012). Mountain Sucker appeared to have been extirpated from much of the southern Black Hills and populations found in the North were shown to be diminishing at multiple scales. Multiple hypotheses were suggested to explain the dramatic diminishment of Mountain Sucker: negative influences of non-native salmonids, drought, and habitat fragmentation (Schultz and Bertrand 2012). Mountain Sucker have also been shown to exhibit intra-seasonal movements which could explain the observed absence of Mountain Sucker from sampled locations (Decker and Erman 1992).

Directed management actions (translocations, non-native fish removals, habitat restoration, etc.) have been recommended to ensure long-term conservation of Mountain Sucker in the Black Hills (Belica and Nibbelink 2006, Dauwalter and Rahel 2008, Schultz and Bertrand 2012). To inform the potential application of these management actions we seek to address knowledge gaps pertaining to the conservation of this regionally imperiled species. Specifically, we addressed the following objectives:

1. Assess the public support for a management strategy that included management of native, non-game fish in the Black Hills of South Dakota.
2. Assess the movement patterns and migration distances of Mountain Sucker.

3. Predict Mountain Sucker distribution using segment-scale habitat variables.
4. Update the distribution of Mountain Sucker for comparison with Schultz and Bertrand (2012).
5. Estimate current trends in density of Mountain Sucker for comparison with Schultz and Bertrand (2012).

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CHAPTER TWO

LOW SURVEY RESPONSE! CAN I STILL USE THE DATA?

This chapter was coauthored with Dr. Larry M. Gigliotti and was published as a research note Human Dimensions of Wildlife

ABSTRACT

Natural resource agencies often use mail surveys to collect stakeholder information. A major concern of mail surveys, however, has long been relatively low response rates compared to telephone or face-to-face interviews. Survey research has been largely focused on achieving high response rates; however, in some situations even well-designed surveys can have low response rates. We present an example of a 3-page (25 questions) survey measuring opinions and attitudes about native fish management in the South Dakota Black Hills region that received a relatively low response rate (21%) using a mailing, postcard, and second mailing of the questionnaire. We compared response rate and data quality of a third mailing of the full questionnaire with a one-page (5 questions) questionnaire measuring key variables to evaluate possible nonresponse bias. Within the *total survey error* (TSE) paradigm we provide evidence that reliable and useful information was collected by this survey.

Key Words: Mail surveys, response rates, nonresponse bias, saliency.

INTRODUCTION

Natural resource agencies often use mail surveys to collect stakeholder information with response rate traditionally being one indicator of survey quality. Response rates, however, measure only the potential for nonresponse bias (Brown, Decker, & Connelly, 1989; Fisher, 1996; Groves, 2006; Kaminska, McCutcheon, & Billiet, 2010; Kreuter, 2013; Peytchev, 2013; Peytchev, Baxter, & Carley-Baxter, 2009; Wagner, 2012). A low response rate does not always signify poor quality data or useless information (Crompton & Tian-Cole, 2001; Groves, 2006; Groves et al., 2006). In cases where survey populations are fairly homogeneous, nonresponse bias will not be an issue and effort taken to increase response rate uses resources that could be better used elsewhere (Becker & Iliff, 1983; Brown et al., 1989; Connelly, Brown, & Decker, 2003; Kreuter, 2013). On the other hand, there are many cases for which respondents and non-respondents have different attitudes and behaviors associated with natural resource issues that should not be ignored if the purpose of the survey was to generalize results to the population (Armstrong & Overton, 1977; Becker, Dottavio, & Mengak, 1987; Brown & Wilkins, 1978; Crompton & Tian-Cole, 2001; Groves, 2006).

A major concern of mail surveys has long been the relatively high nonresponse rate compared to telephone or face-to-face interviews (Brown, et al., 1989, Czajka & Beyler, 2016). Telephone surveys, however, have become more difficult as contacted individuals are increasingly unwilling to comply, and increased sampling effort has been required with the growing popularity of cell phones, answering machines and Caller ID (Groves, 2006) To that end, survey research has focused on achieving high response rates from mail surveys (Dillman, 2008, Smyth and Christian, 2014). However, in some situations even well-designed surveys can have high nonresponse. For such cases, adhering to fixed standards for survey response rates may preclude some research due to budget/staff limitations or waste agency resources chasing down reluctant respondents via expensive procedures (Armstrong & Overton, 1977; Becker et al., 1987; Crompton & Tian-Cole, 2001; Groves, 2006; Lin & Schaeffer, 1995). For example, the U.S. Office of Management and Budget (OMB) require researchers to conduct an analysis of non-response bias for government-sponsored surveys with less than an 80 percent response rate (OMB, 2016). While not identifying a specific methodology, OMB recommendations are suggestive of following a *total survey error* (TSE) paradigm for addressing nonresponse bias. The TSE framework defines survey quality more broadly by including a variety of user-specified dimensions of quality with the main goal of maximizing data quality subject to budget and timeliness constraints (Biemer, 2010; Groves & Lyberg, 2010).

Within the TSE paradigm a distinction is made between survey error and survey accuracy: survey error is a deviation of survey results from its underlying true (sample) value resulting from biases and mistakes in the survey process (e.g., inadequate sampling frame, interviewer or question wording biases, missing data, and coding mistakes). Survey accuracy is defined as a deviation of survey estimates from its underlying true parameter (population) value (Biemer, 2010). The survey error concept incorporates five additional dimensions of data quality beyond accuracy: relevance, timeliness, accessibility, interpretability, and coherence (Brackstone, 1999; Groves & Lyberg, 2010). Juran and Gryna (1993) made a distinction between data producers, who place a high value on the accuracy dimensions, and data users, who also place a high priority on these additional five dimensions of data quality. Of these five dimensions, OMB (2016) guidelines particularly focus on data relevance, or the intended use of the data, as playing a role in the importance of addressing survey non-response. For example, data determined to be “influential,” meaning the information collected can have “… a clear and substantial impact on important public policies or important private section decisions,” should be held to a higher standard of quality compared to information not defined as influential (OMB, 2016; p. 60).

Finding cost-effective ways to address issues of non-response will become ever more important as it is well documented that survey response is declining (Connelly et al., 2003; Czajks & Beyler, 2016; Groves, 2006; OMB, 2016). An increasing number of wildlife agencies are conducting human dimensions surveys for a variety of purposes, for which non-response can play a varying degree of importance in relation to data quality (Decker, Riley & Siemer. 2012). For example, decisions may involve choosing to expend limited resources to achieve a very high response rate to conduct one survey or choosing to conduct three surveys using less expensive methods to address potential non-response bias. Another trend is the increasing popularity of web-based surveys which are well documented as having low response rates (Duda and Nobile, 2010; Gigliotti, 2011; Gigliotti & Henderson, 2015; Kaplowitz, Hadlock, & Levine, 2004; Vaske, Jacobs, & Sijtsma, 2011).

One method for estimating the effect of nonresponse uses comparisons of responses following successive waves of mailings of the questionnaire and is based on an assumption that later respondents (i.e., respondents more reluctant to initially respond) are more similar to non-respondents (Armstrong & Overton, 1977; Crompton & Tian-Cole, 2001; Czajks & Beyler, 2016; Groves, 2006; Lin & Schaeffer, 1995). In considering this method to evaluate nonresponse bias, we examine a case where a mail survey on a natural resource topic received a less than anticipated response rate. We expanded our study to evaluate: (a) if a third mailing of the full questionnaire would have significantly improved the response rate, and (b) whether survey length/complexity was a contributing cause of nonresponse by evaluating the response to a third mailing with a much shorter questionnaire.

METHODS

We developed a questionnaire to measure South Dakota Black Hills residents' attitudes toward native fish management in the Black Hills. The questionnaire was four pages in length with the first page being a short cover letter explaining the purpose of the survey and emphasizing that the survey was for all residents, not just anglers. This first page also included a color photo of a Black Hills stream and a color picture of the Mountain Sucker (*Catostomus platyrhynchus*). The cover letter also stated that if they did not want to participate, they could return a blank survey and they would not be sent any additional requests to participate in the study.

We provided the following information at the top of the second page before the questions:

> "Native fish" refers to any fish species found in the Black Hills that was <u>not</u> stocked into Black Hills streams or lakes. All trout species and other game fish, such as Yellow Perch, Northern Pike, Smallmouth Bass, and Largemouth Bass were stocked into the Black Hills at one time and are **<u>not</u>** "native" fish. Game, Fish and Parks (GFP) is required to manage native species to ensure their long-term survival. Fish native to the Black Hills include: Mountain Sucker, White

> Sucker, Longnose Sucker, Longnose Dace, and Creek Chub. For the purposes of this survey, native fish management in the Black Hills would involve maintaining native fishes in sections of <u>streams</u> that currently offer little to no trout fishing.

We then followed this information with a set of 18 questions measuring opinions about fisheries management in general and specifically about management of native fishes in the Black Hills on a seven-point scale ranging from strongly disagree to strongly agree. These questions were designed to segment people based on their opinions about the management of native fishes in the Black Hills. These questions also allowed respondents to think about the many aspect of native fish management before responding to the dependent variable in our study; attitude towards having some streams in the Black Hills that managed for native fishes (measured on an oppose/favor seven-point scale).

On the last page of the questionnaire, we asked the respondent if they considered themselves an angler (person who fishes) and if yes, we asked anglers to indicate how important fishing was compared to all their other recreational activities (5-point scale from not important to fishing was their most important recreational activity), if they had a preferred fish species, and how often they fished in streams in the Black Hills (5-point scale ranging from never to very often). We ended the questionnaire by asking gender and age and leaving space at the bottom one-third of a page available for optional comments.

We surveyed a stratified random sample of 4,200 Black Hills residents (700 from each county; Butte, Meade, Lawrence, Pennington, Custer, and Fall River; proportional to the total number of each zip code available within or near the Black Hills for each county) (list purchased from Survey Sampling, Inc.). We initiated the survey about mid-August (2017) with a postcard reminder sent about 2 weeks after the initial mailing (hereafter, referred to as "Wave 1"). We provided postage-paid, business reply envelopes with all our mailings. Our follow-up mailing of the questionnaire to non-respondents was sent in early October (hereafter, referred to as "Wave 2"). With this survey design we anticipated about a 50 percent total return rate based on previous experience conducting public opinion surveys with this population, our use of a relatively short questionnaire, our request that recipients not interested in this topic could return their blank questionnaire, and especially, our thoughts that the public would be interested in this topic. Our response rate, however, was much lower than anticipated: 21% completed return rate.

Due to the low response rate we devised a plan to estimate the nonresponse bias, following recommendations provided by Sakshaug and Eckman (2017). Working with a limited budget we randomly selected 620 addresses from the 2,710 non-respondents and then randomly divided them into two groups of 310 each. We mailed one group the full questionnaire with the only difference from the previous mailings being the removal of the identification number (since this was our last mailing) and we included a small (3 by 8 inch), yellow card with an extra appeal to help us with this study by stating that we would like to get opinions from everyone, not just anglers (hereafter, referred to as "Wave 3.1"). We sent the other group a one-page letter (same as the original first page of the questionnaire also without an identification number) asking them to complete the few questions on the back of the letter and return their questionnaire (hereafter, referred to as "Wave 3.2"). This short questionnaire had the same information about native fish management as noted above, followed by our dependent variable (attitude towards having some streams in the Black Hills managed for native fishes), the next question asked the respondent if they considered themselves an angler (person who fishes) and if yes we asked anglers to indicate how important fishing was compared to all their other recreational activities, followed by the two demographic variables of gender and age. We sent these two third-wave mailings in mid-November and data collection ended January 3, 2018.

RESULTS

"Wave 1" had a 15% total return rate (2% blank and 13% completed) and "Wave 2" had an 11% total return rate increasing the total return rate to 24% (3% blank and 21% completed) (Table 1). "Wave 3.1" produced 17 completed questionnaires (6.2% return rate), for which we estimated that a third mailing of the complete questionnaire sent to all non-respondents would have added an additional 171 complete questionnaires for a total return rate of 29% (4% blank and 25% complete). "Wave 3.2" produced 16 completed questionnaires (5.2% return rate), for which we estimated that a mailing of the short, one-page questionnaire sent to all non-respondents would have produced 141 completed short surveys for evaluating nonresponse bias.

Due to insufficient sample sizes from "Wave 3.1" (n=17) and "Wave 3.2" (n=16) we did not analyze responses separately, instead combining the results as "Wave 3". Our main variable of interest was attitude towards management of native fishes in the Black Hills and there was no significant difference among the three mailing waves (Table 2). Gender and mean age were not related to mailing wave (% females by wave: 26%, 29%, and 23%; χ^2 = 1.21, df = 2, p = .547, Cramer's V = .04) (mean age by wave: 60, 59, and 60; ANOVA F (2; 697) = 0.13, p = .877, η = .02).

The percent of respondents who identified as an angler decreased by mailing wave (74% anglers, 64%, and 53%; χ^2 = 12.18, df = 2, p = .002, Cramer's V = .13), although among the anglers, ratings of the importance of fishing was not related to mailing wave (χ^2 = 6.98, df = 8, p = .539, Cramer's V = .08). Overall 69% of the survey respondents classified themselves as anglers compared to an estimated 45% of the Black Hills adult population being anglers (Gigliotti, 2012). A higher percent of anglers (76%) expressed a favorable attitude towards management of native fishes in the Black Hills compared to non-anglers (61%) (χ^2 = 30.20, df = 2, p < .001, Cramer's V = .20). Non-anglers were more neutral or had no opinion (33%) compared to anglers (15%), and few anglers (9%) and non-anglers (6%) were opposed to having some streams in the Black Hills managed for native fishes. We received 125 blank questionnaires, of which 35 people (28%) provided comments either saying that they don't fish, haven't fished in a long time or they are not interested in this survey.

DISCUSSION

This research note presented a case study demonstrating one example of a low response survey providing reliable and useful information. We do NOT suggest that potential nonresponse bias can be ignored; rather in some cases, nonresponse bias can be evaluated with minimal expense and limited additional survey burden. We conclude that most of the Black Hills residents did not have strong negative opinions of the type of native fish management proposed by the South Dakota Game, Fish and Parks Department

(SDGFP). This conclusion was based on: (a) low response rate after three mailing waves, (b) survey length not being a factor suppressing response rate, (c) most respondents reporting favorable attitudes towards management of native fishes in the Black Hills, and (d) the number of blank questionnaires returned specifically stating non-interest in the topic.

In addition to providing data to estimate potential bias due to nonresponse, our third mailing wave was designed to help explain why our initial estimate of response rate was low. Being able to predict response rates is important in estimating sample size needed to meet study objectives and budget accordingly (Brown et al., 1989; Czajka & Beyler, 2016; Dillman et al., 2014). We initially hypothesized two potential reasons for the low response to our survey: (a) survey complexity, or (b) lack of interest in the topic. Although the length of our questionnaire was relatively short, the list of 18 questions on the second and third pages of the questionnaire may have appeared overly burdensome (complex), especially considering the focus on a narrow topic (Greer, Chuchinprakarn, & Seshadri, 2000). On the other hand, in spite of natural resource and wildlife issues, in general, being relatively salient to a large percent of the public in this area, the topic of native fish management may not have been as interesting as we had estimated. The results from our third wave mailing show that complexity was not an important reason for nonresponse; therefore, we conclude that most of the Black Hills residents, and especially non-anglers, were not interested in the general topic of native fish management. Many researchers have reported a strong relationship between interest in the survey topic and survey participation (Connelly et al., 2003; Groves, Presser, & Dipko, 2004; Groves et al., 2006).

Given that a low response rate indicates a potential for nonresponse bias we contend that the results do represent reasonably accurate information for the SDGFP's use of the information. The purpose of the survey was to measure the resident's general beliefs about and attitudes towards native fish management in the Black Hills and to identify the extent and nature of any opposition to the general idea of native fish management. The SDGFP is currently conducting biological studies related to native fish management but decisions to implement any specific management actions will occur in the future and will not be based on results from this survey; therefore the information would not be classified as "influential" by OMB's definition, suggesting that less intensive measures can be employed to evaluate nonresponse bias. Also, our limited nonresponse survey (Wave 3) determined that spending more time and effort to collect responses beyond the second mailing wave would not add any new information or useful insight into this issue other than non-respondents being less interested in the topic. Essentially, the public is relatively homogeneous in their level of neutral to positive support towards the general concept of native fish management in the Black Hills (residents opposed to the idea would probably have the strongest motivation to respond to the survey; Smith, Leahy, Anderson, & Davenport, 2013).

General survey advice suggests that, within budgetary constraints, surveys should be designed to achieve the highest response possible (Dillman, et al., 2014). Yet, for many cases, nonresponse is going to be a continuing issue for mailed surveys (including web-based surveys) that researchers will need to consider during the planning phase (e.g., identifying an appropriate response rate for each survey based on how the information will be used and how nonresponse will be addressed for surveys that do not achieve acceptable response rates). Our example here demonstrated that using additional waves of mailings or incorporating other expensive means of contacting nonrespondents would not have provided any additional useful information on this particular topic. Every research situation is unique and we encourage exploring creative ways to address nonresponse issues.

For deciding about how much effort should be used to estimate the degree of nonresponse bias it would be helpful to have an understanding of the reasons for nonresponse. One suggestion would be to provide a response option to not participate in the survey, with one of the options being “not interested in this topic.” Some other response options could be “too busy at this time,” “don’t trust the agency,” don’t do surveys.” This allows the survey recipient to respond to your request and provides you with more information than no response. One suggestion for future research would be to evaluate the use of providing an option to not participate by providing the opt-out question to half of the sample and evaluating the quality of data received from the split survey sample.

One final point that we propose, regarding lessons learned from this study is that not only would extra effort to contact reluctant respondents on this issue be a waste of SDGFP resources, it might generate negative attitudes towards the agency. After two to three attempts to solicit a response to survey fails, some people may get annoyed from repeated attempts. From the non-respondents’ perspective the agency would be viewed as wasting money on a survey topic that their nonresponse should have indicated that they were not interested in participating. One avenue for future research would be to evaluate the extent and nature of negative attitudes towards the agency resulting from repeated attempts to solicit survey responses.

Limitations. We identified that residents were mostly neutral to favorably in support of native fish management; however, we caution that peoples' general attitude about native fish management may not be a very strong predictor of attitude towards adopting native fish management in specific streams (Ajzen, & Fishbein, 1977; Jaccard, King, & Pomazel, 1977).

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Table 1. Black Hills native fish management survey return rates by South Dakota Black Hills residents (2017).

Mailing[1]	Initial Sample Size	Number Undeliverable	Blank Returns	Completed Returns	% Blank Returns	% Completed Returns	Cumulative Completed Returns
Wave 1	4,200	561	68	470	2%	13%	13%
Wave 2	3,101	61	54	276	2%	9%	21%[2]
Wave 3.1	310	0	3	17	1%	5%	25%[3]
Wave 3.2	310	0	1	16	< 1%	5%	--

[1] Wave 1 included a postcard reminder, Wave 2 did not have a postcard reminder, Wave 3.1 used the complete questionnaire, and Wave 3.2 used the short questionnaire.

[2.] (470+276)84200-(561+61)=.208

[3] Estimated return if a third mailing of the questionnaire was sent to all non-respondents.

Table 2. Attitude towards management of some selected Black Hills streams for native fishes comparing mailing waves.

Mailing	Mean Attitude[1]	Oppose	Neutral	Favor	Number
Wave 1	1.4	10%	18%	72%	63
Wave 2	1.4	5%	23%	72%	155
Wave 3	1.5	6%	22%	72%	547
Total	1.4	8%	20%	72%	765

[1] Attitude scale: -3 = strongly oppose, -2 = moderately oppose, -1 = slightly oppose, 0 = neutral, 1 = slightly favor, 2 = moderately favor, 3 = strongly favor

[1] ANOVA: F (2; 762) = 0.06, p = .942, η = .01

Chi-square: χ^2 = 7.39, df = 4, p = .177, Cramer's V = .07

CHAPTER THREE

SUPPORT FOR NATIVE FISH MANAGEMENT IN THE BLACK HILLS OF SOUTH DAKOTA

This chapter is formatted for submission to the Prairie Naturalist and was co-authored by Dr. Larry M. Gigliotti

ABSTRACT

Fisheries management has traditionally focused on the preservation and proliferation of fishes valued by the managing society. Typical management has almost exclusively focused on game fish. Recent trends in societal values have extended the management of fisheries to include non-game species. Several native, non-game species have been recognized as “Species of Greatest Conservation Need” in the Black Hills Region of South Dakota. Properly assessing the management options for these regionally imperiled species includes, assessing the societal attitudes towards the active management of native species. A stratified-random sample of Black Hills area residents (4,200) were surveyed using a modified Tailored design method (24% return) to assess attitudes towards native, non-game fisheries management in the Black Hills. A market segmentation approach was applied to segment respondents and factor analysis was used to define attributes of each group (apathetic, utilitarian, and conservation). Group support for native, non-game fisheries management differed although mean support was positive for each group.

KEY WORDS Factor Analysis, Market Segmentation, Native Fish, Nongame Fish, Public Support

INTRODUCTION

The historic prioritization of species-based management resulted in the delineation of “game” and “non-game” species (Leopold 1986). Game species can be broadly characterized as those that exhibit increased recreational and economical value. Freshwater fisheries management in North America has traditionally focused on game species whilst largely ignoring population trends exhibited by non-game species until a critical conservation threshold is either eminent or already been surpassed (Clarkson et al. 2005). Recent trends in societal values, renewed emphasis on ecosystem management, and the establishment of the Endangered Species Act may be shifting public support toward more holistic, conservation-based management emphasizing the role of non-game species as vital components of functioning ecosystems (Beamesderfer 2000, Tyus and Saunders 2000, Manfredo et al. 2003, Clarkson et al. 2005, Manfredo et al. 2009, Teel and Manfredo 2010, Verbrugge et al. 2013, Jacobs et al. 2014).

The Black Hills of South Dakota represent a regionally unique ecosystem (Middle Rock Mountain, Level 3) (Omernik 1987). A dome-shaped uprising surrounded by short and mid-grass prairie, the Black Hills can be characterized by dense stands of ponderosa pine (*Pinus ponderosa*) and abundant streams flowing from the core outward onto the surrounding prairie (Berry et al. 2007). Although the mechanism of fish colonization in the region is unknown, a unique native species assemblage can be found within the numerous coldwater habitats. The Black Hills contain regionally unique habitats for a variety of stream-dwelling species which are often disjunct from conspecific populations, putting them at greater risk for local extirpation.

Of the six coldwater species native to the Black Hills, three have been identified as species of conservation need in the region (Table 1) (SDGFP 2006, Berry et al. 2007).

Two of these species have experienced significant local range contractions and are isolated to single drainages (hydrologic unit code 8). Despite being the most widely distributed Catostomid in North America, the longnose sucker, *Catostomus catostomus*, is only found in the Redwater drainage in the northern hills. Lake chub, *Couesius plumbeus*, was historically distributed throughout local streams, but has only been validated in one stream since 1988 (Bailey and Allum 1962, SDGFP unpublished data).

The remaining species, Mountain Sucker, *Pantosteus jordani*, is still widely distributed throughout the Black Hills streams. However, recent studies have indicated negative trends in both overall distribution and local abundance across the region (Dauwalter and Rahel 2008, Schultz and Bertrand 2012, Schultz et al. 2016). Recent trends in local Mountain Sucker populations increase the likelihood that for local species persistence to occur, an active management approach may be needed.

The native stream fish assemblage of the Black Hills has been highly altered due to a variety of mechanisms: unauthorized introductions, mining, logging, grazing, urbanization, and management activities (Berry et al. 2007, Schultz et al. 2012, Schultz et al. 2016). The coldwater native species assemblage is composed of species typically considered to be non-game (Table 1). Trout were introduced into the streams of the Black Hills in 1886 by local residents (Berry et al. 2007) (Table 1). Following introduction, several species of trout have become naturalized and are actively managed to provide recreational fishing opportunities in the region. The addition of non-native fish can have pronounced effects on native fish assemblages (Fausch and White 1981, Garman and Nielsen 1982, Minns 1990, Mcintosh et al. 1992). One such fish, the Brown Trout (*Salmo trutta*) has been observed to exhibit predatory interactions with native fishes in the Black

Hills streams (Schultz and Bertrand 2012, Rowles et al. *Unpublished data*) and although the true impact of this on a population scale is unknown, it is likely negative.

Conservation ethics dictate that managers consider mechanisms that aid in the conservation of biodiversity (Leopold 1966). The economic value associated with game fish bias management activity toward species with easily perceived economic values and away from often cryptic, non-game species. Recent trends suggest broader, public support for holistic, conservation-based management (Manfredo et al. 2003, Manfredo et al. 2009, Teel and Manfredo 2010). By considering local support for including a management goal of maintaining regional biodiversity management agencies can better align their priorities with the broader public values.

The Black Hills region provides a unique opportunity to explore public opinions towards native, non-game fish management in an environment where management resources have historically been devoted to the management of non-native, game species. The Black Hills Stream Management Plan recognizes the need for conservation efforts concerning regionally imperiled species and outlines 5 different wild-fish management strategies: 1) Natural Yield, 2) Memorable Trout, 3) Unique Trout, 4) Improvement, and 5) Native Fish (Galinat et al. 2015). Several authors have suggested management strategies that may help conserve these regionally imperiled species (Isaak et al. 2003, Belica and Nibbelink 2006, Dauwalter and Rahel 2008, Schultz and Bertrand 2012, Schultz et al. 2016). However, public support for allocating resources towards management of these non-game species has not been evaluated.

Opinions towards fisheries management vary within different regions, societies, and stakeholder groups (Duda et al. 1998, Øystein and Arlinghaus 2009). Furthermore, conflicts often exists within and between management agencies when considering the amount of management that should be dedicated to nongame species (Clarkson et al. 2005). Accounting for these opinions when considering management options is critical for maintaining the public trust and, by extension, the effectiveness of management agencies (Decker et al. 1996). Segmentation approaches can be used to delineate groups within a public (Romberg 1999). By identifying the underlying characteristics and values that define market segments, managers can coordinate management decisions that will more likely meet the desires of local stakeholders (Gigliotti 1989, Pollock et al. 1994, Ditton 1996). Our study applies a market segmentation approach to assess Black Hills residents' opinion towards a native fish management option in the Black Hills, region.

METHODS

Survey Design

We developed a questionnaire to assess South Dakota Black Hills residents' attitude toward a management strategy that explicitly included management for native fishes in regional streams. The questionnaire was printed on 11 inch by 17 inch paper and folded in half. Our cover letter was printed on the front page of the questionnaire. Our cover letter stated the overall purpose of the survey, requested that an adult 18 or older whose birthday was closest to the date the questionnaire was received respond to the survey, stated an estimated time of 5 to 10 minutes to complete the questionnaire, and identified who was conducting the survey and how the information collected would be used. The cover letter also included a color photo of an example of a Black Hills stream suitable for maintaining an assemblage of native fish species and a color photo of a Mountain Sucker.

To minimize confusion concerning what species were and were not "native" Black Hills species we included the following statement at the top of page 2:

> "Native fish" refers to any fish species found in the Black Hills that was not stocked into Black Hills streams or lakes. All trout species and other game fish, such as Yellow Perch, Northern Pike, Smallmouth Bass, and Largemouth Bass were stocked into the Black Hills at one time and are **not** "native" fish. Game, Fish and Parks (GFP) is required to manage native species to ensure their long-term survival. Fish native to the Black Hills include: Mountain Sucker, White Sucker, Longnose Sucker, Longnose Dace, and Creek Chub. For the purposes of this survey, native fish management in the Black Hills would involve maintaining native fishes in sections of streams that currently offer little to no trout fishing."

This statement was followed by 18 questions developed to assess opinions towards fisheries management and management of native species measured on a seven-point scale with response options ranging from strongly-disagree to strongly-agree with a mid-point designated as "neutral". Our independent variable in this survey was measured by asking respondents:

> "How strongly do you oppose or favor a management approach that includes maintaining native fishes in sections of streams while still maintaining recreational fishing in other areas of the Black Hills?"

Responses to the independent variable were generated on a seven-point scale from strongly-oppose to strongly-favor with a mid-point designated as neither oppose nor favor. The 18 questions about various aspects of fish management and native fish species preceded our attitude question to ensure that respondents considered a number of aspects about native fish management before answering the main attitude question. The final page of the questionnaire asked if each respondent was an angler, their preferred fish species, whether they fished in the Black Hill's streams, gender, and age. These questions were used to further describe our segments. Ten biologists/staff from the South Dakota Game, Fish, and Parks Department reviewed and provided input in the development of the questionnaire.

A stratified random sample of 4,200 residents was selected from a purchased mailing list (Survey Sampling Inc.) The sample was proportionally stratified by zip codes located within the six county area that included a portion of the South Dakota, Black Hills (700 per county). Our survey commenced in August, 2017 with a postcard reminder sent two weeks after the initial mailing, and a final round of questionnaires was distributed to non-respondents in October, 2017 (Dillman 2008). Each questionnaire was accompanied with a postage-paid, addressed envelope to encourage return rate. Data collection ended January 3, 2018.

Analysis

The 18 opinion questions were used to segment respondents using k-means cluster analysis. We evaluated solutions of 2 to 5 clusters and selected a 3-cluster solution based on criteria (identifiability, substantiality, variation in market response, and exploitability) suggested by Kikuchi (1986). Principal axis factoring was used to reduce the 18 opinion items to represent similar constructs. Identified factors and Cronbach's alpha were used to develop three standardized scales ranging in value from -3 to +3. We used the opinion scales with one-way ANOVA to describe our three population segments. Levene's test was used to assess data variance and Tamhane's T2 post-hoc test was used to identify differences among the three clusters. We summarized our 7-point independent attitude variable to three levels: opposed (slightly, moderately and strongly), neutral, and favor (slightly, moderately, and strongly) due to some small cell sizes and used a Chi-square test to compare the attitude of our three population segments. Segment demographic information was compared using one-way ANOVA. Statistical analysis were conducted in SPSS v 25 (SPSS Inc. 2005) and significance was considered with $\alpha = 0.05$.

RESULTS

Of the 4,200 surveys distributed, a total of 622 were undeliverable yielding an effectively sampled population of 3,578 individuals. Of the returned surveys (n = 868) 86% were completed (n= 746), generating a usable response rate of 21%. Although response rate was much lower than anticipated, the reliability, and by extension the applicability, of this data was confirmed (Gigliotti and Fopma 2019).

K-means cluster analysis was applied to respondents who completed all 18 opinion questions (n=655) yielding our 3-cluster solution, which we named: Conservation (N=368, 56.2%), Utilitarian (N=145, 22.1%), and Apathetic (N=142, 21.7%).

Factor analysis identified four factors representing the 18 opinion questions (Table 2). Three of the identified factors were used to develop reliable scales (Native Fish, Game Fish, and Non-management) for discriminating among our three segments (Table 2). These three scales were significantly different among our three segments and were used to describe our segments based on respondents' opinions towards native fish management (Figure 1). The Conservation segment had the highest support concerning the importance and value of native fish while also showing positive support for game fish. The Utilitarian segment was more positively associated with the game fish scale and was negative towards native fish management. The Apathetic segment was broadly characterized by “no opinion” responses and a “hands-off” approach to management.

Support for a management approach including native fish differed among the three segments (Table 3). The Conservation segment was significantly more supportive of native fish management in the Black Hills compared to the other two segments, with 84% of the segment favorable and only 2% opposed. Although the Utilitarian and Apathetic segments had statistically similar mean attitudes, the Utilitarian segment had a higher percent favorable (64% vs. 47%), while a higher percent of the Apathetic segment had no opinion (neutral) compared to the Utilitarian segment (43% vs. 18%) (Table 3).

Although the Conservation segment had a slightly younger mean age, the more conservative Tamhane’s T2 post-hoc test indicated no significant difference among the three segments (Table 4). The Utilitarian and Apathetic segments were composed of higher percentages of male respondents (88% and 80% respectively) compared to the Conservation segment (65%) (Table 4). The Utilitarian segment had the highest proportion of anglers (87%), followed by the Conservation segment (70%) and then the Apathetic segment (55%) (Table 4).

DISCUSSION

A reliable understanding of stakeholder opinions is essential for effective management to take place. Higher response rates typically lead to more reliable conclusions if the survey is applied appropriately, but this does not necessarily mean that the surveys with lower response rates never provide reliable data. Our survey response was much lower than anticipated (21%) and yet the trends observed are likely valid (Gigliotti and Fopma 2019).

Market segmentation approaches are commonly applied across disciplines to obtain and define stakeholder groups. In natural resource management, these approaches have been effective in defining values, attitudes, and user types of a variety of stakeholder groups (Adams 1979, Cole and Scott 1999, Lai et al. 2009, Kim and Weiler 2013, Gigliotti and Dietsch 2014, Gigliotti and Chase 2017). In this study, we used a market segmentation framework to assess regional attitudes toward a fisheries management strategy that included native, non-game fish species in addition to managing for non-native, game species. We observed three primary market segments in this study that were defined by differences in their responses to 18 questions concerning fisheries management in the region. These 18 questions were reduced using PCA to generate unique factors that were then used to define three unique market segments: Conservation, Utilitarian, and Apathetic. Notably, the Conservation segment was largest (56 %) within the population surveyed. This segment also favored management of native species significantly more than the other two segments. Despite differences in relative favorability of native fish management, overall favorability scores were positive for all three segments. This is representative of a broader trend of increased support for the active management of native, non-game species.

Several management strategies have been proposed for one of the native species in the Black Hills. Local trends in Mountain Sucker distribution and abundance (Isaak et al. 2003, Dauwalter and Rahel 2008, Schultz and Bertrand 2012) have indicated that action is likely needed to locally conserve this species. A negative association with non-native salmonids is commonly observed for native-non-game species (Garman and Nielsen 1982, Mcintosh et al. 1992, McIntosh 2000, Rowles et al. 2019) dictating that management for native species likely should be separate from traditional stream management focused on providing sport-fishing opportunities via the proliferation of wild trout (Galinat et al. 2015).

MANAGEMENT IMPLICATIONS

This study represents a unique case where active management of native fish is potentially limited by a desire to maintain and increase non-native game species. Given the popularity of game species and their importance as economic and recreational resources it is unlikely that management will ever shift entirely away from introduced game species (salmonids). Our findings indicate regional support for a management strategy that includes prioritizing the conservation of native, non-game fish species.

A wide variety of management tools could be applied for the conservation of native species: designated conservation streams, removal of non-native species, habitat restorations, etc.

Although all segments generally supported a native fish management strategy, educational programs would also likely increase regional awareness and support for non-game, native species (Alvey 2006, Buijs et al. 2008). By integrating native fish into the management strategy, it is likely that the Black Hills would continue to support robust populations of non-native game species as well as restored populations of native, non-game species.

LIMITATIONS

Our study identified South Dakota, Black Hills residents' general attitudes as mostly neutral to favorably supportive towards native fish management. However, we caution that peoples' general attitude about native fish management in the Black Hills may not be a very accurate predictor of attitude toward adopting native fish management in specific streams (Ajzen and Fishbein 1977, Jaccard et al. 1977).

Note: Any use of trade names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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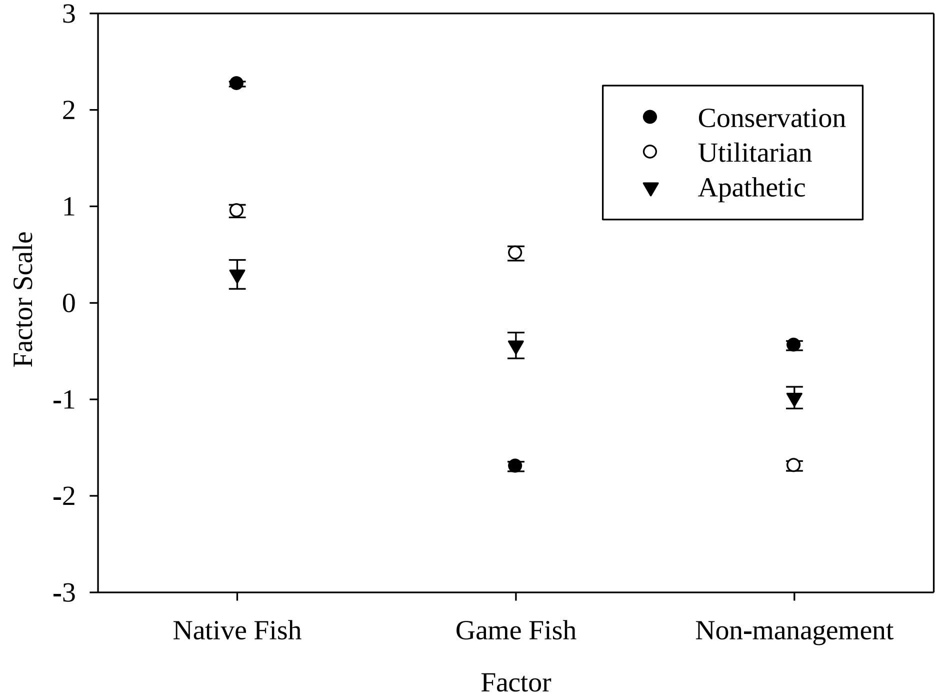

Figure 1. Mean segment score and SE for each of the three factors. Significant differences existed between mean scores for each factor (Conservation: $F_{(2,652)} = 440.79$ $P < 0.001$ $\eta = 0.76$, Utilitarian: $F_{(2,652)} = 459.62$ $P < 0.001$ $\eta = 0.67$, Apathetic: $F_{(2,652)} =$ 30.37 $P < 0.001$ $\eta = 0.29$)

Table 1. Common and native coldwater species of the Black Hills of South Dakota.

Species	Type	Game or Nongame Species	Species of Conservation Need
Brook Trout (*Salvelinus fontinallis*)	Introduced	Game	
Brown Trout (*Salmo trutta*)	Introduced	Game	
Creek Chub (*Semotilus atromaculatus*)	Native	Nongame	
Longnose Dace (*Rhinichthys cataractae*)	Native	Nongame	
Mountain Sucker (*Pantosteus jordani*)	Native	Nongame	X
Rainbow Trout (*Oncorhynchus mykiss*)	Introduced	Game	
Longnose Sucker (*Catostomus catostomus*)	Native	Nongame	X
Lake Chub (*Couesius plumbeus*)	Native	Nongame	X
White Sucker (*Catostomus commersonii*)	Native	Nongame	

Table 2. Opinion prompts concerning fisheries management reduced to four factors using Principal axis factoring with Varimax rotation method and Kaiser Normalization (convergence reached after 6 iterations). *Factor was generated but was not informative and was dropped from analysis.

Prompt	Rotated Factor Matrix			
	Factor 1	Factor 2	Factor 3	Factor 4
Q1A	0.615	-0.151	-0.103	0.184
Q1B	0.817	-0.346	0.161	0.039
Q1C	0.864	-0.332	0.159	-0.005
Q1D	0.868	-0.342	0.160	-0.029
Q1E	0.419	-0.167	0.170	0.222
Q1F	0.326	-0.108	0.111	0.277
Q1G	0.281	0.114	-0.100	0.267
Q1H	0.131	0.179	0.038	0.518
Q1I	-0.186	0.472	-0.294	0.121
Q1J	-0.158	0.662	0.128	0.259
Q1K	0.527	-0.454	0.157	0.193
Q1L	-0.252	0.700	-0.034	0.017
Q1M	0.069	-0.034	0.701	-0.015
Q1N	0.131	-0.077	0.853	-0.003
Q1O	-0.093	0.379	0.049	0.389
Q1P	-0.179	0.503	-0.069	0.052
Q1Q	0.324	-0.452	0.217	0.168
Q1R	0.117	-0.033	-0.089	0.660

Factor 1: Native Fish

Cronbach's alpha = 0.865

Q1A Conservation of fish is important to me.

Q1B Managing native fish is important to me.

Q1C Native fish are important for maintaining stream health.

Q1D Native fish are important in the environment.

Q1E We should remove non-native fish only if they harm native fish.

Q1F Native fish compete for resources with non-native fish.

Q1K Native fish populations should be monitored for signs of distress/decline.

Factor 2: Game Fish

Cronbach's alpha = 0.746

Q1I Native fish have little recreational value.

Q1J GFP should only manage fish that are consumed by humans.

Q1L GFP should not manage for native fish conservation.

Q1P Only some streams should be managed for native fish.

Q1Q Native fish should be stocked in areas where they are rare or in decline. (reverse coded)

Factor 3: Non-management

Cronbach's alpha = 0.768

Q1M Non-native fish should not be stocked.

Q1N GFP should remove non-native fish.

Factor 4*

Cronbach's alpha = 0.513

Q1H Streams should be managed for economic value.

Q1R Streams should be managed for fishing.

Non-scaled questions

Q1G Native fish are an important food for non-native fish.

Q1O GFP should manage fish that are consumed by humans regardless of impact on native fish.

Table 3. Attitude towards native fish management in the Black Hills by population segments.

Summarized Attitude[1]	Conservation	Utilitarian	Apathetic
Oppose	2%	18%	10%
Neutral	14%	18%	43%
Favor	84%	64%	47%
Total Number	364	141	140
Mean Attitude[2, 3]	2.0[a]	0.8[b]	0.7[b]

[1] $\chi^2 = 100.23$, $P < 0.001$, Cramer's $V = 0.28$

[2] 7-point mean attitude scale: -3 (strongly oppose) *to* +3 (strongly favor)

[3] $F_{[2;\,642]} = 66.59$, $P < 0.001$, $\eta = 0.41$ (similar superscripts are statistically similar at the $P = 0.05$ significance level based on Tamhane's T2 post-hoc test)

Table 4. Demographics recorded for the three population segments.

Demographics	Conservation	Utilitarian	Apathetic	*F*	*P*	*η*
Mean Age (years)	58[a]	61[a]	61[a]	3.45	0.032	0.11
Percent Male (%)	65[a]	88[b]	80[b]	15.49	<0.001	0.22
Percent Angler (%)	70[a]	87[b]	55[c]	17.81	<0.001	0.23

Means in each row with similar superscripts are statistically similar at the $P = 0.05$ significance level based on Tamhane's T2 post-hoc tests.

CHAPTER FOUR

MOVEMENT OF MOUNTAIN SUCKER *PANTOSTEUS JORDANI* IN WHITEWOOD CREEK

ABSTRACT

Understanding movement potential is essential when considering the potential for natural recolonization following local extirpation events. We assessed movement and home-range size of a fish that has been locally extirpated from much of its historic range in the Black Hills of South Dakota. We compared gross and net movement and home-range size of 30 Mountain Sucker at two different locations within Whitewood Creek, SD over the course of two separate tagging events. We found no difference between movements or home-ranges size between tagging rounds or tagging locations. Net movements and home-range size were small indicating a lack of intra-seasonal migrations and high site fidelity. Individual movements were also small except for one individual that displayed a large movement (>1 km) shortly after tagging followed by minimal movement. Mountain Sucker have been observed to exhibit spawning migrations in other portions of their range; however, this was not observed in this study. Understanding movement potentials for this species will guide management actions and restoration monitoring efforts.

INTRODUCTION

Historic fisheries management has focused on the maintaining and proliferating game fish (Clarkson *et al*. 2005, Cooke *et al*. 2005). The management of lotic systems is similar in this regard with a majority of historical management practices focusing on maintenance of navigable channels, hydrologic control, and abundant populations of game fishes. Cold, headwater streams are no exception to this historic pattern of management with particular attention being devoted towards the management of salmonids. Recent trends in fisheries management has placed a new emphasis on the management of non-game species.

Mountain Sucker (*Pantosteus jordani*) is one of three Catostomid species native to the Black Hills of South Dakota. Though once abundant throughout the regional, recent studies (Schultz and Bertrand 2012) have indicated significant declines in both abundance and occupied range since the 1960's. Cooke et al. (2005) proposed several mechanisms that could be limiting the success of catostomids across North America (i.e. loss of connectivity, hybridization, introduced species, etc.).

A benthic, rheophillic, fish, Mountain Sucker is found through the mountainous terrain of western North America. Recently redefined into 11 different species across their collective range (Unmack et al. 2014). Considered to be generally secure throughout its range (NatureServe 2019), fringe populations have been observed to be in regional decline in both abundance and local distribution (Decker 1989, COSEWIC 2010, Schultz and Bertrand 2012). Fringe populations are often regionally disjunct due to drainage separation and habitat alteration (Isaak et al 2003). The Black Hills are no exception to this trend as they contain the eastern-most population of Mountain Sucker.

The disjunct nature of populations can be readily observed locally in the Black Hills due to the locally unique, geological phenomena. Surveys conducted 2007-2010 indicated that Mountain Sucker had been completely extirpated in 5 of the 10 major watersheds in the region (11-digit hydrologic unit code; Schultz and Bertrand 2012). This decline in regional distribution coupled with trends in local abundance raised concern about local genetic isolation. Genetic drift was observed to be the primary factor directing genetic structure of Mountain Sucker populations in six different Black Hills streams (Bertrand et al. 2016). The observed genetic similarity between populations was attributed to relatively recent periods of stream connectivity or anthropogenically directed dispersal (authorized or unauthorized fish movement) of Mountain Sucker across local drainages.

Several mechanisms have been theorized that could have contributed to the local isolations of Mountain Sucker in the Black Hills: anthropogenically derived barriers, naturally dewatered zones, drought, thermal barriers and introduced species (Williamson and Carter 2001, Dauwalter and Rahel 2008, Schultz and Bertrand 2011, 2012). Incumbent to management for Mountain Sucker is an understanding of mechanisms (i.e. movement, trap and transfer, unauthorized movements) that will allow for spatial redistribution throughout the Black Hills.

Several studies have referenced pre-spawn movements of Mountain Sucker (Decker 1989, Wydoski and Wydoski 2002), however a direct assessment of movement has not been conducted (Isaak et al. 2003). Stream morphology varies within Whitewood Creek as it transitions from the mountainous center of the Black Hills onto the surrounding prairie. I assess the movement of Mountain Sucker in a mountainous and prairie portion of Whitewood Creek to test for differences in movement scale and home-range size. Understanding local movement patterns will inform management decisions concerning potential stream repatriation efforts in the Black Hills region.

Study Area

The Black Hills represent a regionally unique ecosystem in the shortgrass prairies of the north-central Great Plains. Part of the Middle Rockies Level III ecoregion (Omernik 1987), The Black Hills are characterized by their dense stands of ponderosa pines, *Pinus ponderosa*, numerous spring-fed streams and unique geologic formations. Whitewood Creek originates in the north central Black Hills near Englewood, SD and flows northeast out of the hills and across the prairie until its eventual confluence with the Belle Fourche River near Vale, SD. The creek hosts 13 different species of fish (Table 1) and can be broken into 3 primary sections.

The upstream section (Zone 1) (29.6 km) originates at the headwaters extending into a canyon approximately 5.1 km downstream of Deadwood, SD. The stream then flows 7.7 km through a canyon of limited accessibility and unknown connectivity north to Crook City, SD (Zone 3). The upper section is more narrow than the downstream section (mean width = 6.9 m.) and is characterized by pool-riffle-run sequences and high-gradient (2.5%; Olivero and Anderson 2008). The downstream section (Zone 2) extends from the base of the canyon flowing predominantly across the prairie persisting to the confluence with the Belle Fourche River (38 km). Zone 2 can be characterized by a lower gradient (0.8%) and an increased mean width (9.7 m). The section also exhibits higher species richness (Table 1) which is likely associated with diversity of habitats found within the transition from a cold, mountainous stream to a cool prairie stream. Zones 1 and 2 of Whitewood Creek are separated by a largely inaccessible canyon section (Zone 3) (7.7 km, Figure 1). Little is known concerning connectivity, habitat, and fish populations through this reach.

Whitewood Creek became was the site numerous gold-activities that date back to the 1870s. Primary gold production was located in Zone 1 near Lead, South Dakota resulting in over 25 million tons of mine tailings being deposited into the Whitewood Creek watershed (HUC 11, U.S.E.P.A. 2017). The effects of mining in the region were pronounced resulting downstream portions of Whitewood Creek (Zone 2) being designated as a superfund site by the Environmental Protection Agency in 1983. Superfund site remediation efforts occurring in 1991-1993 resulted in the removal of the site from the national priorities list in 1996 (U.S.E.P.A. 2017). Increases in water quality have resulted in the return of many stream-dwelling organisms, including the establishment of robust populations of native and non-native fish species. Zones 1 and 2 are routinely surveyed to evaluate stream restoration practices in addition to monitoring fish populations as part of the Black Hills Streams Stream Fish Management Plan (SDGFP 2006).

METHODS

Fish Collection, Tagging, and Locations

To evaluate movement, Mountain Sucker were tagged in Zones 1 and 2 of Whitewood Creek (Figure 1). Mountain Sucker were collected via backpack electrofishing (Smith-Root, LR24 Electrofisher, Vancouver, Washington). Tags (Lotek Wireless, Model NTF-3-2 [0.57 g. in air], Newmarket, Ontario) were externally attached

(Beaumont et al 1996)) to Mountain Sucker. To minimize handling time fish were not anesthetized prior to tagging. Tags were attached into the dorsal musculature posterior to the insertion of the dorsal fin. Stainless steel wire (0.64mm diameter) was passed through the external attachment structure on the radio tags to ensure proper orientation when attached. A single strand of wire was then passed through the dorsal musculature of the fish superior to the spinal column using a hypodermic needle. The tag end of the wire was passed over the fish and the two ends were secured and trimmed to minimize drag or risk of the tag snagging on benthic debris or aquatic macrophytes. Tags were attached streamside and fish were held post-tagging until normal behavior was observed. Upon resumption of normal behavior fish were returned to the stream in areas of slack current at the location of capture.

Thirty Mountain Sucker were tagged during this study. The first round of tagging occurred May 2018 and consisted of 10 fish with five fish tagged in each zone. The second round of tagging, consisting of 20 fish occurred September 2018 with 10 fish being tagged in each zone (Figure 1). Tagged fish varied in size and weight, (135-198 mm total length (TL) and 29-96 g) minimum size for tagging Mountain Sucker was set at 29 g to meet the “2% rule” of tag mass to body mass, recommendation (Winter 1983, 1996).

Tracking began 24 hours post release in all locations. Tracking surveys were conducted at least four times during the seven days post-release and then weekly for the duration of the transmitter battery life or until the end of the tracking period (December 7, 2018). During each round of tracking, fish were disturbed at least once, using either physical displacement or a backpack electrofishing unit to confirm the vitality of the fish.

Locations of fish in the stream were estimated from the streamside using the "zero-point tracking" methods described by (Cooke et al. 2012). Fish locations were determined using a Biotracker receiver (Lotek Wireless, Newmarket, Ontario.) paired with a three element Yagi antenna (Model F150-3FB 14318, AF Antronics, Urbana, Illinois) and recorded using Survey123 for ArcGIS app. To help ensure accuracy, GPS coordinates were determined using a Bad Elf GNSS Surveyor hand-held GPS (Model BE-GPS-3300) with an accuracy of, ±2.5 m (Bad Elf, Tarriffville Connecticut).

Movements and Analysis

Assigned locations of radio tagged fish were assessed using ArcGIS (version 10.2.2). If assigned locations were not located directly on stream imagery, presumably due to GPS error, the point was moved to the nearest stream bank. Distances between locations of tagged fish were measured in meters through the center of the stream for each recorded location. Upstream movements were assigned a positive value and downstream movements were assigned negative movements. With these measurements, gross movement, and home range were calculated. Gross movement was calculated as the sum of the absolute value of all movements per individual tagged fish. Home range was calculated for each individual fish by measuring the distance between the furthest observed upstream location of each fish and the furthest observed downstream location of each fish.

Differences in mean gross movement and home range assessed using a mixed model analysis of variance tagging round and tagging zone applied as fixed effects and fish applied as a random effect. Alpha was set equal to 0.05 for all statistical tests and all test were conducted in R (RCoreTeam 2019).

RESULTS

A total of 309 locations were assigned to fish during this study. During the first round of tagging (May 10-29, 2018), four tags were lost within a week of deployment presumably due to tag failure. One additional fish was removed from further analysis due to the observation of an exceptionally large movement. This fish made two consecutive downstream movements within two weeks of tagging of 210 and 1,820 meters. Following the second movement downstream the fish was located in a pool where it remained for the duration of the transmitter battery life. This fish was removed do the dissimilarity of its largescale movement with the observed moments of other tagged fish. During the second round (September 28, 2018) 10 fish were tagged in each zone. Prior to analysis an additional three tags, from the second round of tagging, were removed from further analysis due to a low number of observations (<5). The remaining 22 fish were used in all future analysis. Round 1 fish were tracked for an average of 140 days and round 2 fish were tracked for an average of 40 days. Movements analyzed for the 22 remaining fish included 80 locations assigned to fish tagged during the first round and 207 locations assigned to the fish tagged during the second round (11 in each tagging zone).

Movement patterns were similar between tagging rounds (Table 2, Figure 2). Mean gross movement was similar between tagging rounds (590 m and 420 m during the first and second rounds respectively). Home ranges averaged 290.5m and 179.9 m for the first and second rounds, respectively and were statistically similar ($P > 0.05$).

Mean gross movement was similar for each zone and was observed to be 408.9 m for the upstream section and 511.3 m for the downstream section. Mean home range sizes for the upstream and downstream sections were 186.5 m and 223.6 m and were statistically similar ($P > 0.05$, Figure 3).

DISCUSSION

The movements of large-bodied catostomids have been comparatively well studied (Bunt and Cooke 2001, Cooperman and Markle 2003, Sweet and Hubert 2010, Booth et al. 2013) (Scott and Crossman 1973). Large scale (>30 km) movements and home ranges have been observed for several species of catostomids (Pattenden et al. 1991., Modde and Irving 1998, Mueller et al. 2000). In contrast, we observed notably less movement of Mountain Sucker in a Black Hills stream than that reported for several other species of catostomids.

Despite the growing body of literature surrounding catostomid movements, limited information exists examining the movement patterns of small, stream-dwelling catostomids such as the Mountain Sucker. Several authors have observed presumed pre-spawn movements of Mountain Sucker (Hauser 1969, Decker 1989, Wydoski and Wydoski 2002) although these movements have not been directly quantified. Sweet and Hubert (2010) quantified the movements of four lotic-dwelling catostomids in a Wyoming river noting broad variability in the timing, and magnitude of pre- and post-spawning movements. General catostomid movements are greatest during the spring and are related to both discharge and thermal conditions (Grabowski and Isely 2006, Jeffres et al. 2006, Sweet and Hubert 2010, Fraser et al. 2017). White Sucker is the only sympatric catostomid found in Whitewood Creek. Sweet and Hubert (2010) observed White Sucker movements were observed to generally occur at a lesser magnitude than other sympatric species. Doherty et al. (2011) noted White Sucker spawning movements of up to 40 km followed by periods of high site fidelity with mean summer home ranges <1 km.

Inherent to any tagging study is the assumption that the tag does not alter the activity of the individual. Mountain Sucker were observed to exhibit high site fidelity during the period of this study (Table 2) indicating that the impacts of tag implantation may have been minimal. Mean home range size was <300 m and did not differ between tagging location or period which is generally smaller than other stream-dwelling catostomids (Doherty et al. 2010, Booth et al. 2014). General movement magnitude of Mountain Sucker in Whitewood Creek was small but one fish did exhibit a large movement (>2 km) within one week of tagging which may have been a response to tag implantation (Figure 4) (Clough and Beaumont 1998).

Locally disjunct populations of stream fishes are common throughout North America. The long-term survival of these populations depends on the ability of individuals to transition between populations over time. Losses of connectivity due to anthropogenic impacts i.e. dams, introduction of alien species, thermal alterations, etc., pose significant risks for many populations (Jelks et al. 2008). Additionally, given connectivity, fish populations must be capable of exhibiting sufficient movements to allow for the exchange of individuals between populations. In this study Mountain Sucker exhibited small home-ranges during the summer (May-September) and fall (September-December) in one Black Hills drainage suggesting that natural dispersal between local populations in this region may be unlikely. Although our results are limited in application to Mountain Sucker found in Whitewood Creek, SD they could also be indicative of movement patterns exhibited by conspecifics. Further research is needed to characterize Mountain Sucker movement more broadly on the species level.

Individual suckers have been observed to exhibit sedentary and mobile phases through time, the variability of which may not have been captured by our sample size (Booth et al. 2014). Our study was initiated at the end of the expected spawning period it is likely that our assessment of home range size and movement potential is conservative. Despite the potential under-estimate of home range size, it is still unlikely that individual exchange occurs between drainages in the Black Hills given the upstream directionality of pre-spawn movements and the unique local geology of the region (Bertrand et al. 2016). Catostomids exhibit spawning movements of variable magnitude (Tyus and Karp 1990, Doherty et al. 2010, Sweet and Hubert 2010). Further research is needed to assess the spawning movements of this catostomid.

MANAGEMENT IMPLICATIONS

Directed management has been recommended for the long-term conservation of Mountain Sucker in the Black Hills (Dauwalter and Rahel 2008, Schultz and Bertrand 2012) (Belica and Nibbelink 2006). Translocation has been a widely applied management tool for a variety of stream dwelling species: trout, darters, topminnows, etc. and has been identified as an effective conservation management tool (Minckley 1995). Given local declines in both distribution and abundance of Mountain Sucker (Schultz and Bertrand 2011) and observed movement patterns of local populations, the utilization of translocation techniques is likely necessary to repatriate streams. Repatriation of locally extirpated streams and increasing local abundances of Mountain Sucker via translocation efforts are likely to enhance genetic diversity of local Mountain Sucker populations and reduce the risk of regional extirpation (Bertrand et al. 2016).

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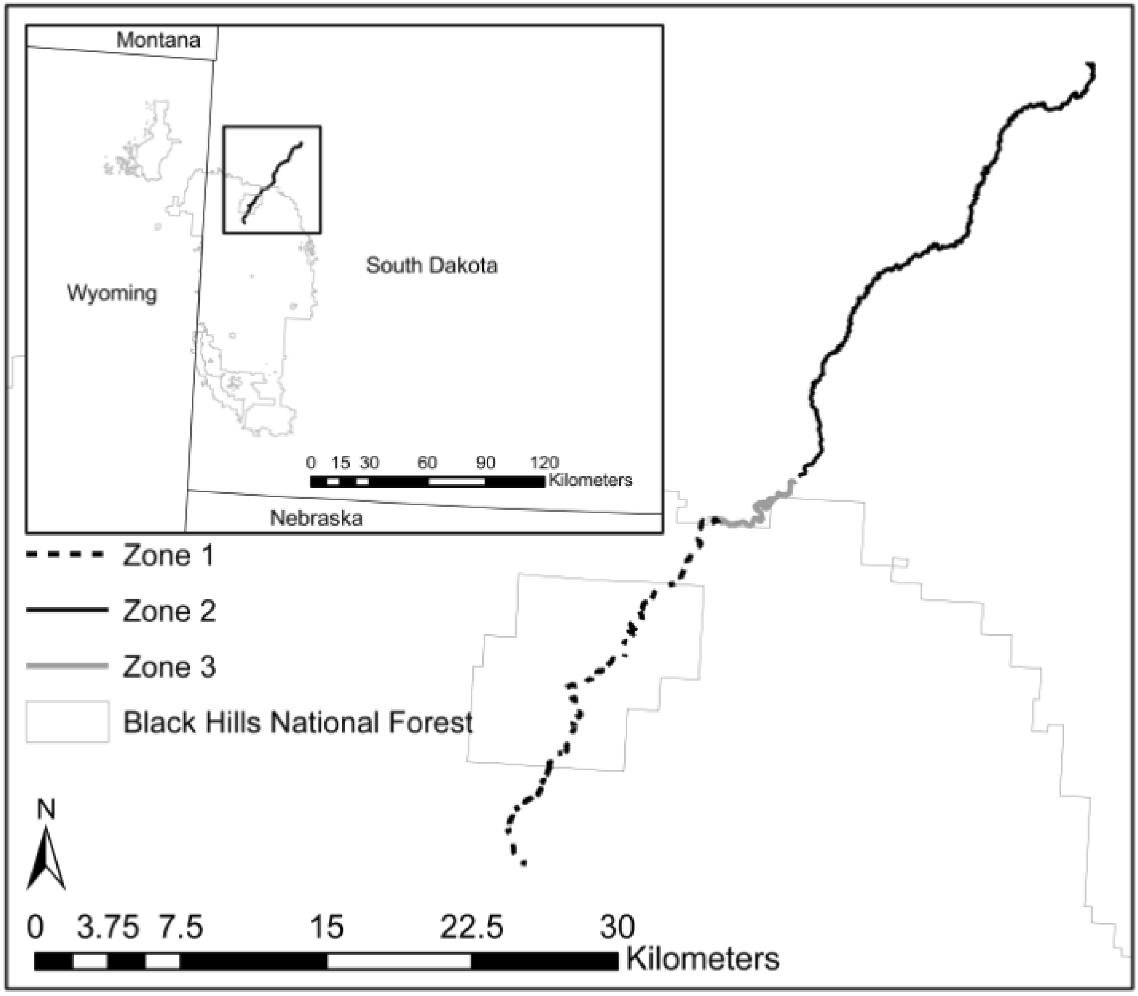

Figure 1. Zones of Whitewood Creek in the Black Hills region of South Dakota.

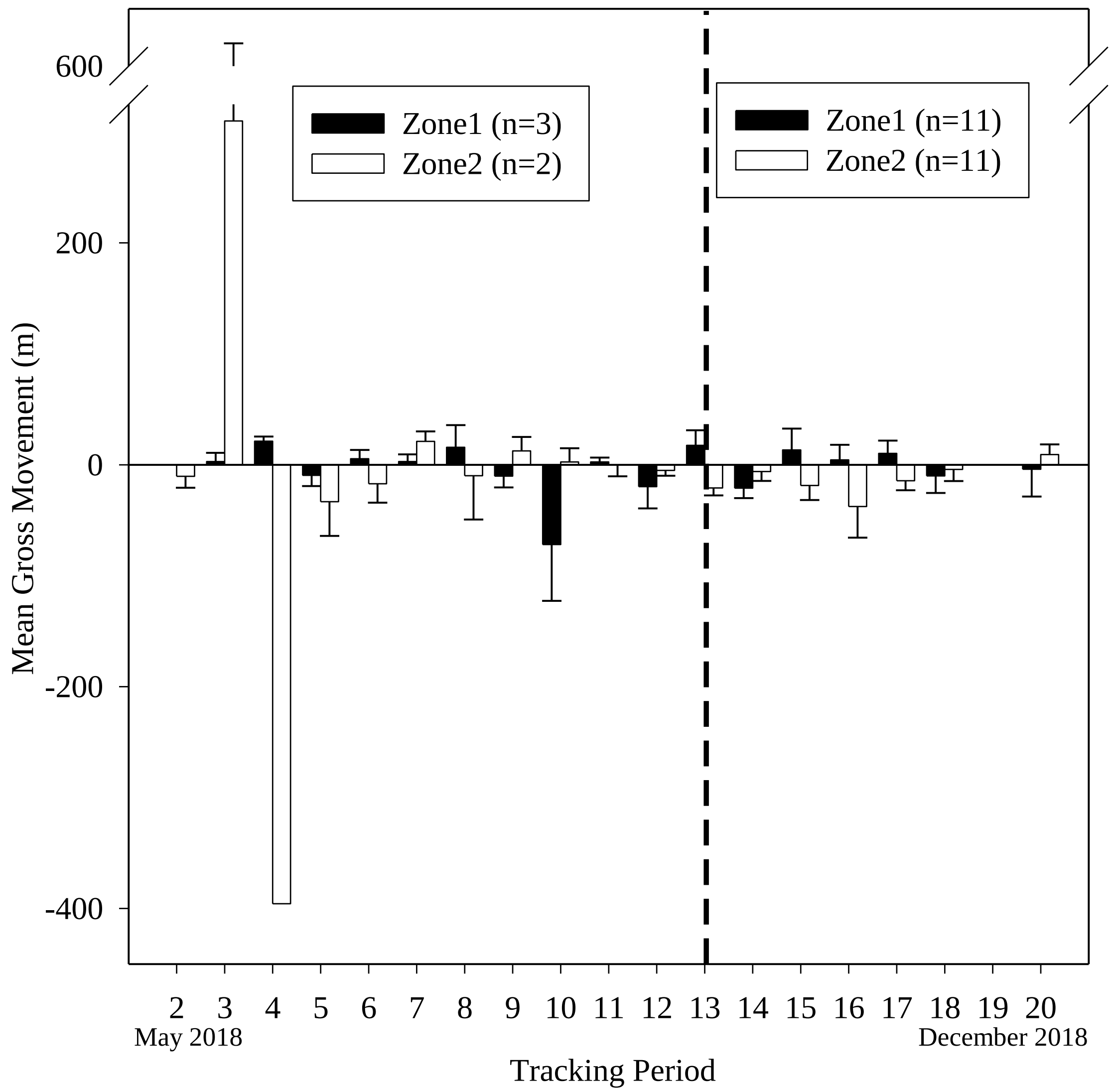

Figure 2. Mean gross movement and SE between tagging zones. The dashed line represents the initiation of the second tagging event (September 28, 2018) and an increase in sample size. Each tracking period consists of 10 days. Positive and negative values indicate upstream and downstream movement, respectively.

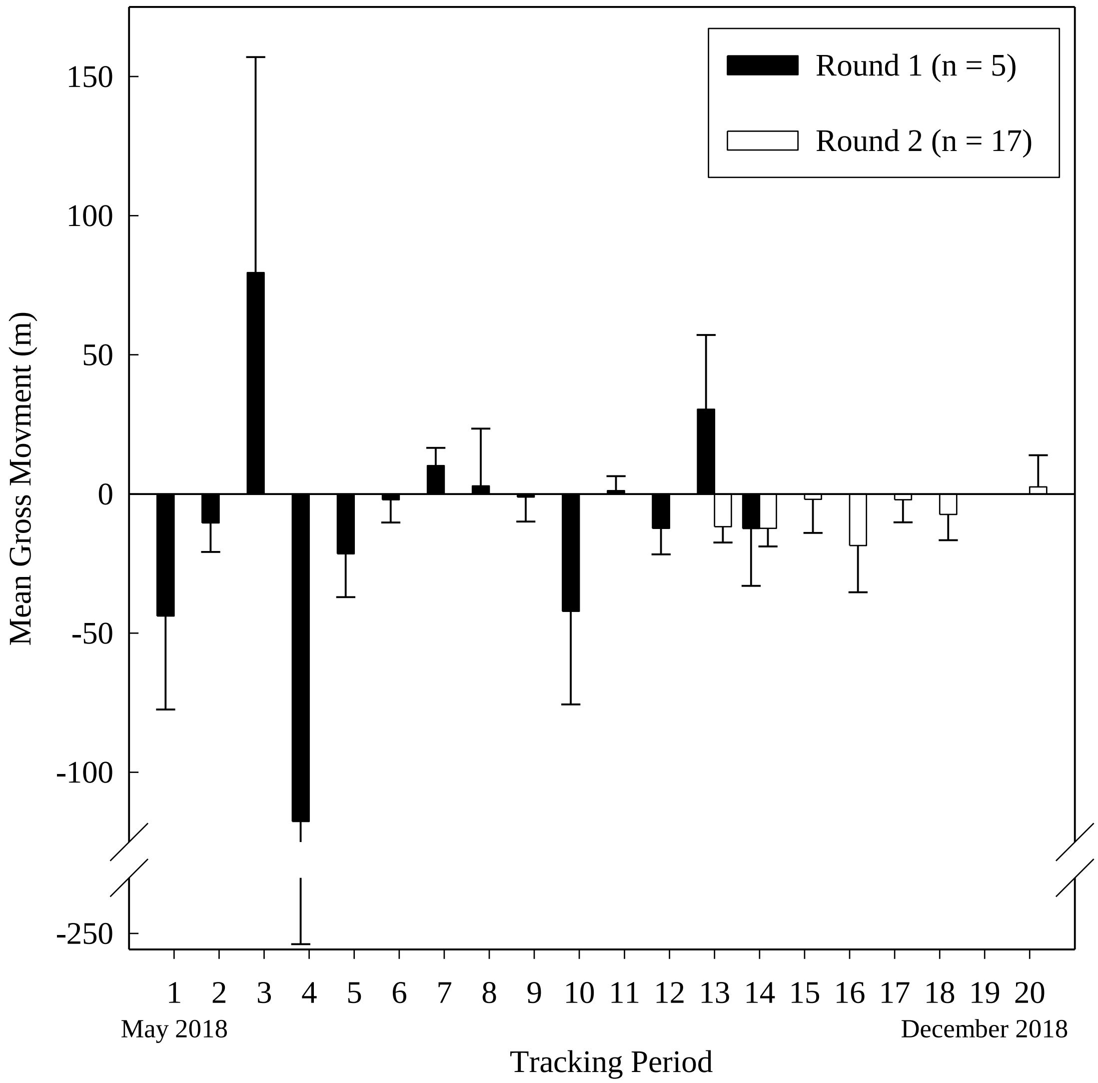

Figure 3. Mean gross movement and SE between tagging rounds for each tracking period (tracking period = 10 days). Positive and negative values indicate upstream and downstream movement respectively.

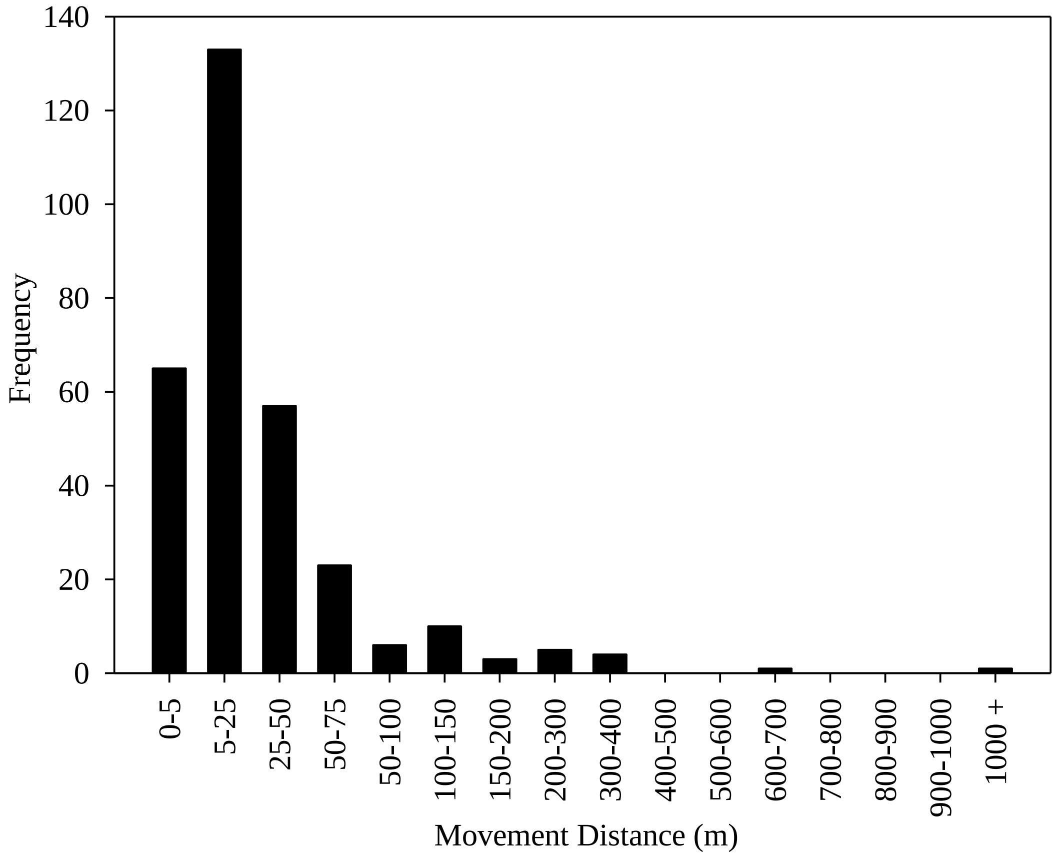

Figure 4. Frequency of recorded movement distance (absolute value) for all observed Mountain Sucker movements (n=309).

Table 1. Species found in the Whitewood Creek (WWC) drainage (HUC 11) Zones 1 and 2 represent the upstream and downstream segments of WWC.

Common Name	**Scientific Name**	**Native to WWC**	**Found in Zone 1**	**Found in Zone 2**
Longnose sucker	*Catostomus catostomus*	x		
White sucker	*Catostomus commersonii*	x		x
Green sunfish	*Lepomis cyanellus*			x
Shorthead redhorse	*Moxostoma macrolepidotum*	x		x
Sand shiner	*Notropis stramineus*			x
Stonecat	*Noturus flavus*	x		x
Cutthroat trout	*Oncorhynchus clarkii*		x	
Rainbow trout	*Oncorhynchus mykiss*		x	
Mountain Sucker	*Pantosteus jordani*	x	x	x
Fathead minnow	*Pimephales promelas*			x
Longnose dace	*Rhinichthys cataractae*	x	x	x
Brown Trout	*Salmo trutta*		x	
Brook trout	*Salvelinus fontinalis*		x	
Creek chub	*Semotilus atromaculatus*	x		x

Table 2. Summary of observed Mountain Sucker, movements and home range (m) by tracking round and zone (SE).

	# of Tags	**# of Locations**	**Mean Gross Movement**	**Mean Home Range**
Round 1 (May-September)	5	80	590.3 (153.7)	290.5 (82.7)
Round 2 (September- December)	17	207	421.9 (64.3)	179.9 (50.7
Zone 1	11	141	408.9 (57.2)	186.5 (29.7)
Zone 2	11	146	511.3 (108.2)	223.6 (84.1)

CHAPTER FIVE

PREDICTED DISTRIBUTION OF MOUNTAIN SUCKER *PANTOSTEUS JORDANI* IN THE BLACK HILLS OF SOUTH DAKOTA

ABSTRACT

Understanding the factors that influence species distribution is an essential step in conservation management. By accurately identifying areas where species are likely to occur, conservation efforts can be targeted to areas where they are most likely to succeed. We developed species distribution models for Mountain Sucker, *Pantosteus jordani*, in the Black Hills region of South Dakota. Mountain Sucker were once widely distributed throughout the Black Hills though recent studies have suggested significant declines at multiple scales. The objective of this study was to evaluate segment scale influences on current Mountain Sucker occurrence. We use an ensemble modeling approach by combining five modeling techniques. Variable importance and response plots were used to evaluate the influence of individual, segment-scale variables. Predictive performance of models was evaluated using the area under the receiver operating characteristic (AUC) score. Mountain Sucker distribution was primarily influenced by mean August stream temperature. These models can be used to prioritize areas for Mountain Sucker assessment and monitoring efforts. Additionally, models can aid in the identification and evaluation of stream segments suitable for conservation efforts throughout the Black Hills of South Dakota.

INTRODUCTION

Interest in the causal relationship between a species' presence or absence and the environment has long been a question for ecologists. The development of species distribution models (SDMs) (also commonly referred to as ecological niche models) has guided current understanding of species-environment relationships for many years. Species-environment relationships are often complex requiring modelers to develop a variety of modeling techniques and accept increased amounts of uncertainty between model results (Morin and Thuiller 2009, Thuiller et al. 2009, Wiens et al. 2009, Li and Wang 2013).

Species distribution models have been used to guide management activities for a variety of lotic species (Rahel and Nibbelink 1999, Weigel and Sorensen 2001, Mugodo et al. 2006, Lyons et al. 2010, Meyer et al. 2013, Bouska et al. 2015, Gobel et al. 2018, Heckel IV et al. 2020). Model predictions can be used to guide stream monitoring strategies and novel sampling locations. Habitat associations can be used to guide management actions including species removal, translocations, and stream habitat alteration or restoration.

Due to the popularity of SDMs, a wide variety of modeling techniques have been developed to address model uncertainties (Guisan and Thuiller 2005, Thuiller et al. 2009, Li and Wang 2013). The availability of spatial data has also attributed to the increased use and development of species distribution modeling techniques in recent years. The development of modern regression and machine learning techniques has increased the interpretability and accuracy of distribution models (Leathwick et al. 2006, Elith and Leathwick 2009, Bouska et al. 2015). Ensemble modeling procedures have been developed as a way to combine predictions from multiple SDMs to form a more accurate prediction overall (Marmion et al. 2009, Morin and Thuiller 2009, Thuiller et al. 2009). Predictions generated from SDMs can be used to guide management decisions that include activities such as species monitoring, habitat restoration, invasive species removal, species reintroductions, etc.

A wide variety of SDMs have been used to assess fish distributions in many different environments (de la Hoz Franco and Budy 2005, Buisson et al. 2008, Lyons et al. 2010, Bouska et al. 2015, Phillips et al. 2017, Gobel et al. 2018, Heckel IV et al. 2020). Distribution models for lotic-dwelling fish species have commonly been limited to game species (Rahel and Nibbelink 1999, Weigel and Sorensen 2001) despite the inherent and ecological value of non-game species (Vanni 2002, Clarkson et al. 2005, Dudgeon et al. 2006). The development of non-game species models is becoming more prevalent in the literature (Lyons et al. 2010, Bouska et al. 2015) reflecting a more holistic approach to fisheries management.

Mountain Sucker is found through the mountainous terrain of western North America and the species is considered secure throughout its range (NatureServe 2019). Recently, the species has been redefined into 11 different species across their collective range (Unmack et al. 2014). The Black Hills of South Dakota contain the easternmost population of Mountain Sucker (McPhail 2007). Mountain Sucker (*Pantosteus jordani*) is one of six coldwater species native to the Black Hills of South Dakota and has been identified as a Species of Conservation Need in the region (Berry et al. 2007, SDGFP 2014). Though once regionally abundant (Bailey and Allum 1962), recent studies (Schultz and Bertrand 2012) have indicated significant declines in both abundance and distribution since the 1960’s. Declines in distribution and abundance have been observed for populations of Mountain Sucker at the extremes of their range including the population found in the Black Hills (Decker 1989, COSEWIC 2010, Schultz and Bertrand 2012). Mountain Sucker in the Black Hills are also regionally disconnected from conspecific populations. Fringe populations, such as the one found in the Black Hills, are often separated by drainage boundaries, anthropogenic influences, and natural hydrologic patterns (Williamson and Carter 2001, Isaak et al. 2003, Dauwalter and Rahel 2008, Schultz and Bertrand 2011, 2012, Bouska et al. 2015).

The Mountain Sucker, historically distributed throughout many Black Hills streams (Bailey and Allum 1962), has been identified as a species of conservation concern in Wyoming and South Dakota (WGFD 2005, SDGFP 2014). Mountain Sucker are also considered and indicator of biological health for the Black Hills National Forest (BHNF) (SAIC 2005). Surveys conducted in the late 2000's indicated that Mountain Sucker had been completely extirpated in 5 of the 10 major watersheds in the region (11-digit hydrologic unit code) (Schultz and Bertrand 2012). This decline in regional distribution coupled with trends in local abundance raised concern about the ability of populations to persist across the region.

The distribution of Mountain Sucker in the Black Hills has been assessed at both the segment (10^2 m) and reach (local, 10^1 m) scale (Frissell et al. 1986). Dauwalter and Rahel (2008) utilized historic data (1988-2004) to identify largescale abiotic factors associated with Mountain Sucker occurrence in the BHNF including stream permanency, elevation, stream, order and stream slope. Schultz et al. (2015) used more recent data (2008-2010) to identify reach-scale habitat variables associated with Mountain Sucker occurrence including substrate size, macrophyte vegetation coverage (%), periphyton coverage (%) stream productivity, and stream discharge. In both studies model fit was improved with the addition of an index of non-native trout in the final model (Dauwalter and Rahel 2008, Schultz et al. 2015).

Although distribution models do exist for Mountain Sucker at both the local and segment scale for Mountain Sucker in the Black Hills region (Frissell et al. 1986, Dauwalter and Rahel 2008, Schultz et al. 2015) it is important to evaluate and update models regularly to account for range contraction and expansion. Major drought occurred across the region from 2002-2007 (NDRP 2020) which could have limited distribution of fish observed during the Schultz et al. (2015) study. Additionally, the ever-changing impacts of anthropogenic activities poses continual potential to significantly impact species distribution throughout the region.

The objectives of this study were to 1) apply modern modeling techniques and available data to model Mountain Sucker distribution across the Black Hills of South Dakota; 2) predict the current distribution of Mountain Sucker in the region using an ensemble modeling (forecasting) technique. Predictions of Mountain Sucker distribution will help guide management decisions by aiding in the prioritization of sampling areas, the potential identification of novel populations, and potential areas of species reintroductions and removals.

METHODS

Study Area

The Black Hills are a heavily forested, dome-shaped uprising located in western South Dakota and eastern Wyoming. The geologic structure of the Black Hills is complex with concentric rings of igneous and sedimentary rocks forming the core that is surrounded by sedimentary rocks as the slopes descend onto the prairie (Williamson and Carter 2001). The sedimentary formations found within the north and east edges of the hills cause localized dewatering in many streams (Loss Zones), in many streams the water returns to the surface at lower elevations. This lack of connectivity is typically observed between the high-elevation headwaters and the comparatively low elevation tailwater prairie streams. Part of the Level III Middle Rockies Ecoregion the Black Hills and are surrounded by short to midgrass prairie effectively isolating the coldwater species within from conspecific populations. The Black Hills fisheries habitats can be characterized by man-made reservoirs and the numerous coldwater streams, the latter streams varying both morphologically and by species assemblage (Dauwalter and Rahel 2008, Schultz et al. 2012). Reasons for variation in stream morphology can partially be related to post-European settlement land management practices and use including, fire suppression, construction of reservoirs, construction of roads, grazing/ranching, mining, timber production and recreational development (Rahn et al. 1996, Brown and Sieg 1999, Hamilton and Buhl 2000, May et al. 2001). The stream fish assemblage has also been altered as a result of European settlement and is composed primarily of three introduced salmonid species: Brook Trout (*Salvelinus fontinalis*), Brown Trout (*Salmo trutta*) and Rainbow Trout (*Oncorhynchus mykiss*). The typical stream assemblage also includes native species Creek Chub (*Semotilus atromaculatus*), Longnose Dace (*Rhinichthys cataractae*), White Sucker (*Catostomus commersonni*), and Mountain Sucker.

Stream Data

Existing stream GIS data bases were used to evaluate the impacts of abiotic covariates on the distribution of Mountain Sucker for the South Dakota portion of the

Black Hills. Steam network habitat variables and modeled temperatures were compiled by NorWeST (Isaak et al. 2017). Streamlines and temperature models were developed to aid in the management and prediction of species distributions that could be impacted by mean stream temperatures during the month of August (Isaak et al. 2017). Data was downloaded for the Black Hills region of South Dakota and Wyoming according to hydrologic unit code (HUC) level 6 watersheds. NorWeST derived data included the following variables: elevation (m), canopy cover (% tree cover), stream temperature (August mean stream temperature [°C] from 1993-2011), and slope (stream channel gradient; Isaak et al. 2017). Additionally, the BHNF generated a stream network data series to aid in forest planning (BHNF 2000). Streamline coverage included the entire Black Hills region and included stream order (Strahler 1957).

Stream data was processed using ArcGIS version 10.2.2 (ESRI Inc., Redlands, CA). BHNF data was spatially joined with the NorWeST data with a tolerance of 100 meters to account for variation between the two data sets. Streamlines were clipped by state boarders to remove portions of the Black Hills region that did not fall within South Dakota. The remaining streamlines were clipped by HUC level 10 to remove areas which did not include streams originating within the BHNF. An additional subset of streamlines was generated by selecting for streams that included a historic, South Dakota Department of Game Fish and Parks sampling location as these would broadly represent streams in which current management and monitoring occurs.

Distribution Data

Mountain Sucker spatial occurrence was assessed at 144 sites from May-August, 2014-2018. Sites were selected according to standard stream monitoring locations and those surveyed during previous studies (Schultz and Bertrand 2012). Block nets were placed at the upstream and downstream ends of each 100 m sampling location prior to sampling effort. Sampling effort consisted of multi-pass depletion backpack electrofishing (Smith-Root, LR24 and 12B Electrofishers, Vancouver, Washington) of the closed stream section (Zippin 1958, Bonar et al. 2009). This survey method has been shown to be effective for sampling Mountain Sucker even at relatively low densities (Dauwalter and Rahel 2008). Fish captured were identified to species prior to release. All sites were surveyed a minimum of two times over the five-year study period. Sites were described to have Mountain Sucker present if the species was observed at a site during the study period. Sampling sites were spatially joined to the stream network using ArcGIS (ESRI Inc., Redlands, CA).

Modeling

This study applied five modeling algorithms that have been previously used to assess the distribution of freshwater fish species (Bouska et al. 2015). Generalized linear models (GLM), generalized boosting models (GBM), Multivariate adaptive regression splines (MARS), classification and regression trees (CTA), and random forest (RF) algorithms were applied using the BIOMOD2 package in R (RCoreTeam 2019) to assess current distribution of Mountain Sucker. Specific algorithms were chosen due to their ability to handle presence and absence data.

Pearson's correlation coefficient was used to assess relationships between the five environmental variables. If variables were strongly correlated ($|r| \geq 0.7$) the variable thought to be least biologically relevant was removed from further analysis (Schober et al. 2018).

When the final set of variables were obtained, a 10-fold cross validation approach was used to generate and evaluate individual models. In total 50 individual models were generated using the five selected algorithms. Data were split randomly into 10 individual datasets where 80% of the available data were used to train/calibrate the model and the remaining 20% not used in model training was used to assess model performance.

Individual models were ensembled using the weighted mean of each individual models evaluation metric (Marmion et al. 2009). The area under the curve of the receiver operating characteristic plot (AUC) was used to evaluate each model. AUC represents the ability of the model to differentiate between sites that are occupied and those where the species is absent. An AUC score of 1 represents a model with 100% correct assignment whereas an AUC score of 0.5 represents a model that is incapable of differentiating between species presence and absence and thus is as good as random chance (Pearce and Ferrier 2000). For an individual model to be included in the ensemble modeling step its AUC score needed to be ≥ 0.75. Model sensitivity (true positive rate) and specificity (true negative rate) were used to calculate the true skill statistic (TSS, sensitivity + specificity – 1). TSS was also used to assess model performance where a score of 0 indicates inability to differentiate presence and absence points and a value of 1 indicated perfect assignment to evaluate model performance (Hanssen and Kuipers 1965, Peirce 1984).

Ensembled model probabilities were used to project current distribution of Mountain Sucker in the Black Hills.

RESULTS

Distribution

Mountain Sucker were observed at 44 of the 144 sites surveyed (Table 1). General distributions of Mountain Sucker were consistent with the observations made by Schultz (2011). Variation in Mountain Sucker were observed at the local level for several streams where densities had previously been found to be low and in areas that had previously been unsampled. During this study, Mountain Sucker were not observed in the several areas where they had been observed by Schultz (2011): Annie Creek, Battle Creek, and. Crow Creek. Conversely, the intensive sampling associated with this study (multi-pass and multi-season) documented the presence of Mountain Sucker in streams that were either unsampled or where Mountain Sucker were classified as absent by Schultz (2011): Flynn Creek, French Creek, Fall River, Slate Creek and Spring Creek.

Modeling

A high level of correlation was observed between elevation and temperature ($|r|$ = 0.75). Due to the biologic relevance of water temperature to Mountain Sucker (Schultz and Bertrand 2011), elevation was removed from further analysis. The remaining four variables (stream order, slope, canopy cover, mean august temperature) were used to model Mountain Sucker distribution. Individual model performance varied yielding AUC scores between 0.54 and 0.88 (average = 0.76) with more complex models (GBM and RF) generally preforming better. TSS scores varied between 0.21 and 0.69 suggesting variability in individual model capability of correctly differentiating between presences and absences.

Ensemble modeling included consideration of all 50 individual models. Individual model scores were subjected to the AUC threshold of 0.8 for inclusion in the ensemble modeling process. The ensemble model was generated using 22 of the 50 individual models. The AUC and TSS scores (0.99, 0.90 respectively) for the ensemble model were higher than those observed for the individual models.

Environmental Relationships

Relative importance of each environmental variable was similar for each modeling algorithm (Figure 2). Response curves were generated relating the four environmental variables to probability of Mountain Sucker occurrence for the model set of each algorithm. Although variability was observed within response curves for each algorithm, general patterns were consistent. Candidate models were primarily influenced by mean August stream temperature. The importance of the remaining environmental variables, varying across algorithms (Figures 2,3). Response curves indicated increased probability of Mountain Sucker occurrence at temperatures between 15 and 24℃ with all but one algorithm (GLM) indicating a more restrictive range ≈ 16 to 19℃ (Figure 3).

Projected Distribution

Predicted occurrence closely aligned with areas of known occurrence following the ensemble modeling process (Figures 1, 4). Model prediction indicates increased probability of occurrence around the periphery of the Black Hills especially in areas with comparatively fewer surveys (Figures 1, 4). When the ensemble model was applied to the entire Black Hills stream network (including steams unsampled during this study) similar patterns were observed. Predictions for the southern portions of the Black Hills indicate increased probabilities of occurrence across the unsampled region (Figure 5). Predicted occurrence closely aligned with areas of known occurrence following the ensemble modeling process (Figures 1, 5).

DISCUSSION

Four environmental variables were used to predict the occurrence of Mountain Sucker across the Black Hills of South Dakota. Data were collected from existing GIS databases (BHNF 2000, Isaak et al. 2017). Mountain Sucker distributions were modeled at the segment scale utilizing spatially joined occurrence data collected at the reach scale (Frissell et al. 1986). Segment scale data included canopy cover, stream slope, stream order, and modeled stream temperature. These variables are commonly used to model the distribution of lotic species at this scale (Dauwalter and Rahel 2008, Meyer et al. 2013, Bouska et al. 2015).

Increases in model performance are observed when individual distribution models were ensembled together (Crimmins et al. 2013, Bouska et al. 2015). Increased predictive performance of distribution models increases the odds of model applicability to management decisions. Ensemble modeling resulting in AUC scores >0.9 indicating ability to discriminate between presence and absence data.

The development of accurate stream temperature models allowed the current study to assess the impact of stream temperature on Mountain Sucker distribution directly. Patterns in response curves indicate a narrow range of temperatures in which Mountain Sucker can exist. Critical thermal maxima (CTM) for Mountain Sucker in the Black Hills was observed to be 31.5-33.4℃ when fish were acclimated to 20-25℃ water temperatures, although Mountain Sucker were not observed at temperatures >27.4℃ during sampling (Schultz and Bertrand 2011). Response curves indicate Mountain Sucker in the Black Hills exist at temperatures well below their thermal maxima but are unlikely to at temperatures below 15 ℃. Water temperature has been informative for the modeling of a variety of lotic species (Ebersole et al. 2001, Buisson et al. 2008, Lyons et al. 2010, Bouska et al. 2015). In Utah, the distribution of Brown Trout was observed to be limited by variations in temperature (de la Hoz Franco and Budy 2005). The distributions of Brook Trout and Brown Trout in southeastern Wyoming were limited by temperature (19-22℃) and stream size constraints addition to other habitat factors (Rahel and Nibbelink 1999).

The influence of stream temperature on species distribution is potentially diminished when multiple species co-occur. Interspecific interactions have the potential to diminish or displace species utilizing the same or similar thermal niches. In the Black Hills non-native trout have been shown to be negatively associated with Mountain Sucker abundance (Dauwalter and Rahel 2008, Schultz et al. 2015, Rowles et al. *Unpublished Data*). Field observed CTM's for the three trout species that occur in Black Hills streams are all >22℃ with a maximum observed CTM ≈26℃ for each species (Wherly et al. 2007). Although this is less than the observed CTM for Mountain Sucker (see above) the reality of overlapping distributions and accompanying displacement is well documented across the Black Hills of South Dakota (Schultz and Bertrand 2012, Schultz et al. 2015).

Previous modeling has suggested that Mountain Sucker distributions are impacted by a variety of interacting factors including those listed above (Gard and Flittner 1974, Dauwalter and Rahel 2008, Schultz and Bertrand 2011, Hayer et al. 2013, Schultz et al. 2015).

Previous work in the Black Hills indicated that Mountain Sucker occurrences were more closely associated with reach-scale habitat variables than variables modeled at the segment scale (Schultz et al. 2015). Of the variables considered at the reach scale substrate size, vegetation coverage, and periphyton coverage were identified as the most informative. Similarly, the Lahotan Basin Mountain Sucker were closely associated with course substrates and overhead cover and were observed to occur in areas following increases in periphyton coverage (Decker 1989). Segment scale variables were used by Dauwalter and Rahel (2008) to model Mountain Sucker distributions in the Black Hills using historic distribution data. Dauwalter and Rahel (2008) modeled the same variables included in the current study apart from stream temperature; stream permanency was also included in their models as well as first-order interactions between all included variables. Stream permanence was the most informative variable for modeling Mountain Sucker presence; however, the inclusion of additional variables and interactions increased model performance. Complex interactions were observed between several variables (Dauwalter and Rahel 2008) indicating that Mountain Sucker distributions are likely regionally restricted by the availability of suitable habitat conditions. Associated variables and their interactions were hypothesized to be related to the cool-water requirement of Mountain Sucker, whereas perennial, high gradient, high elevation and higher order streams regionally consist of cooler water that provides stable, suitable habitat (Dauwalter and Rahel 2008).

Hybridization has been identified as a potential threat to catostomids (Cooke et al. 2005). White Sucker thermal tolerance overlaps with that of Mountain Sucker. Mountain Sucker have been observed to hybridize with co-occurring catostomids in stream environments (Decker 1989, Mandeville et al. 2017). White and Mountain Sucker have been observed to hybridize (McPhail 2007, Mandeville et al. 2017) and are thought to be hybridizing in at least one location in the Black Hills (personal observation). The potential for Mountain Sucker displacement via predation, hybridization, and competition with non-native salmonids necessitates the production of accurate predictive distribution models to guide management efforts.

Model accuracy may be limited when it is applied to spatial extents beyond that of training data (Crimmins et al. 2013). Extending the model to all streams in the Black Hills included many streams that were not sampled during the current study (Figure 1). Sampling coverage was biased towards streams in the northern half of the Black Hills where populations of Mountain Sucker were known to occur (Schultz and Bertrand 2012). Models predict high probabilities of Mountain Sucker occurrence in the southern Black Hills where few locations were sampled. Extending the model to extents beyond the data used to build it can be informative, however, caution should be applied before using model outputs to guide management actions. The accuracy of model predictions in these areas should be assessed through field sampling efforts. Stream reaches in the southern Black Hills were underrepresented during this study and future modeling could be improved with data from this region. Increased occurrence probability for the southern portion of the Black Hills was also noted by Dauwalter and Rahel (2008) further illustrating the need to sample in this region. Watersheds in the southern portion of the Black Hills typically experience less precipitation, resulting in expansive reaches of dry streambed. Sampling in this region should be focused near the headwaters of streams where perennial flow is exhibited including Cascade, Pass, Payne, Pleasant Valley, and Red Canyon Creeks.

Model accuracy can also be limited by the data included in the model building process. Biologically relevant variables may be unavailable at the spatial extent being modeled. For example, stream permanence has been identified as an important variable for modeling Mountain Sucker distribution in the Black Hills but was unavailable at the spatial extent modeled in this study (Dauwalter and Rahel 2008, Schultz et al. 2015). The type of predictor variables included in model building can also influence model performance (Austin 1985). The current model includes both direct and indirect variables. Water temperature directly relates to the physiological processes of Mountain Sucker whereas canopy cover, stream gradient, and stream order are likely indirectly related physiological processes (Austin 2007). The inclusion of species assemblage parameters would likely improve model performance. Brown Trout have been shown to negatively impact Mountain Sucker at the reach scale (Dauwalter and Rahel 2008, Schultz et al. 2015, Rowles et al. *Unpublished Data*) and would likely improve the current model if the data were available.

The current model assumes that stream connectivity exists throughout the Black Hills region. The unique geology of the region, anthropogenic impacts, and municipal obstructions all limit the connectivity of the stream network in the Black Hills.

Additionally, impoundments often support populations of non-native species that could negatively impact distributions of native species. Inclusion of municipal obstructions would likely increase model accuracy over time but would require a more mechanistic modeling approach while concurrently requiring a more intensive dataset (Kearney and Porter 2009).

Despite limitations the current model provides insight into the current distribution of Mountain Sucker throughout the Black Hills of South Dakota. Probability of occurrence was highest around the periphery of the Black Hills and was primarily impacted by stream temperature. Model accuracy is likely impacted by the lack of physiologically relevant variables and would likely be improved with the inclusion of additional variables when they become available. Model predictions should be validated prior to making long-term management decisions. Model evaluation could be conducted by using standard electrofishing methods to assess current stream fish assemblages in areas with high predicted probabilities of Mountain Sucker occurrence. Concurrent with electrofishing efforts should be evaluation of local habitat characteristics and stream permanency to aid in the evaluation location suitability for long-term management of Mountain Sucker.

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Table 1. Sampling reaches (latitude and longitude) where Mountain Sucker were observed during the during the current study and if they were observed (X) during sampling for the previous study Schultz and Bertrand (2012).

Sample Reach	**Schultz & Bertrand 2012**
Bear Butte 44.334N, -103.625W	X
Bear Butte 44.298N, -103.676W	X
Bear Butte 44.307N, -103.669W	X
Bear Butte 44.315N, -103.652W	X
Boxelder Creek 44.157N, -103.466W	X
Boxelder Creek 44.229N, -103.599W	X
Boxelder Creek 44.198N, -103.535W	
Boxelder Creek 44.198N, -103.523W	X
Castle 44.078N, -103.718W	X
Castle 44.081N, -103.717W	
Elk Creek 44.277N, -103.696W	X
Elk Creek 44.298N, -103.583W	X
Elk Creek 44.295N, -103.561W	
Elk Creek 44.302N, -103.553W	X
Fall River 43.403N, -103.412W	
Fall River 43.419N, -103.458W	
Flynn Creek 43.669N, -103.463W	
Flynn Creek 43.685N, -103.473W	
French Creek 43.718N, -103.489W	
Jim Creek 44.146N, -103.504W	
Jim Creek 44.146N, -103.550W	
Meadow 44.294N, -103.560W	
Middle Boxelder 44.198N, -103.700W	
North Fork Rapid 44.132N, -103.736W	X
North Fork Rapid 44.197N, -103.761W	X
North Fork Rapid 44.178N, -103.756W	X
Rapid 44.121N, -103.709W	X
Rapid 44.111N, -103.671W	
Redwater River 44.580N, -104.017W	
Slate 44.032N, -103.634W	
Spring 43.944N, -103.513W	
Tilson 44.178N, -103.777W	X
Tilson 44.174N, -103.799W	X
Whitewood 44.621N, -103.472W	
Whitewood 44.385N, -103.719W	
Whitewood 44.412N, -103.694W	X
Whitewood 44.460N, -103.620W	X
Whitewood 44.366N, -103.734W	
Whitewood 44.474N, -103.627W	X

Whitewood 44.518N, -103.608W	X
Whitewood 44.622N, -103.471W	X
Whitewood 44.589N, -103.520W	X
Whitewood 44.396N, -103.703W	X
Whitewood 44.442N, -103.630W	

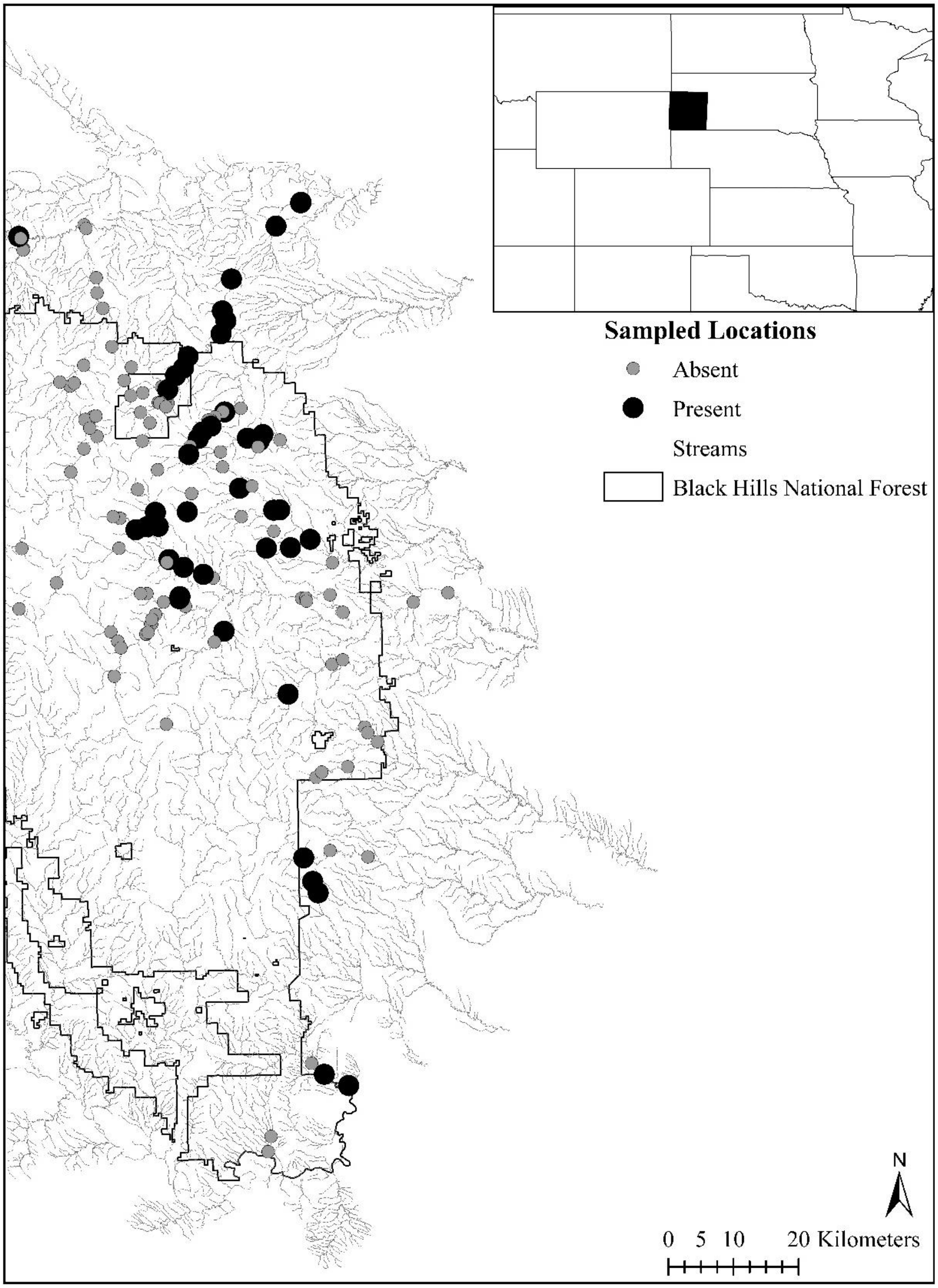

Figure 1. Stream sampling locations for the 2014-2018 study period. Surveys were conducted between May and September of each year and each site was visited at least twice during this study.

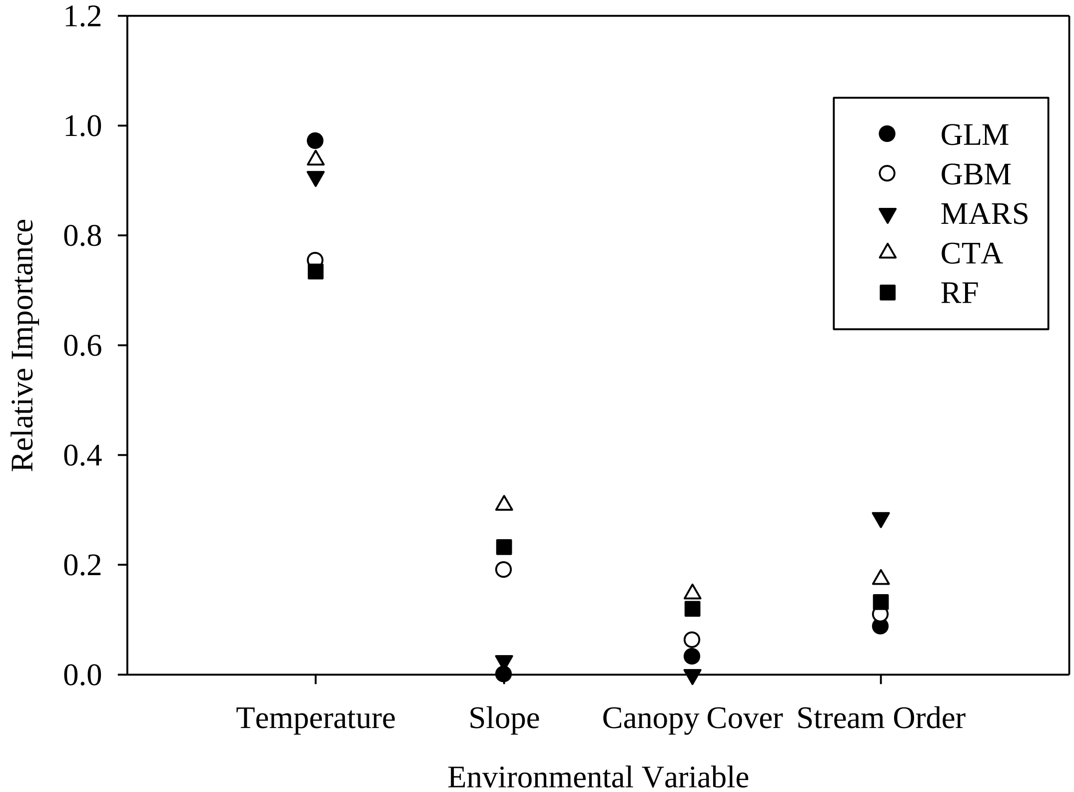

Figure 2. Relative variable importance averaged across all model runs (10) for each algorithm.

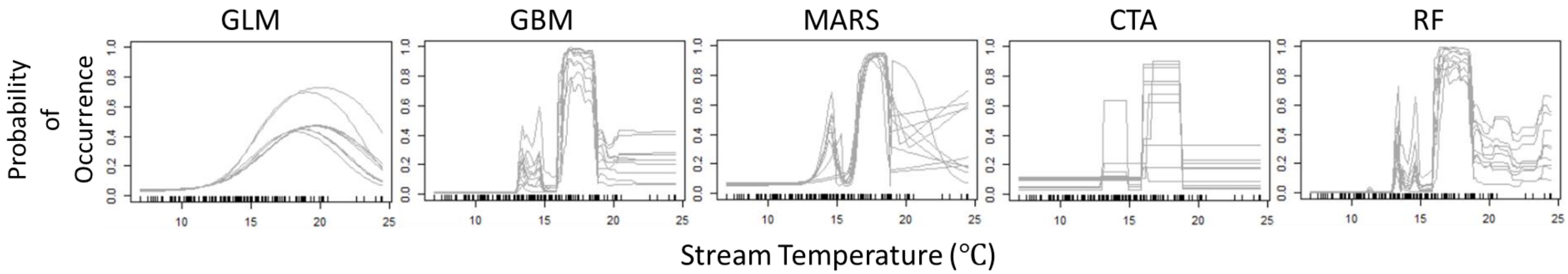

Figure 3. Response curves for the probability of occurrence of Mountain Sucker relative to modeled stream temperature for each of the five algorithms used to construct the ensemble model. Each individual model was run ten times as illustrated within each panel.

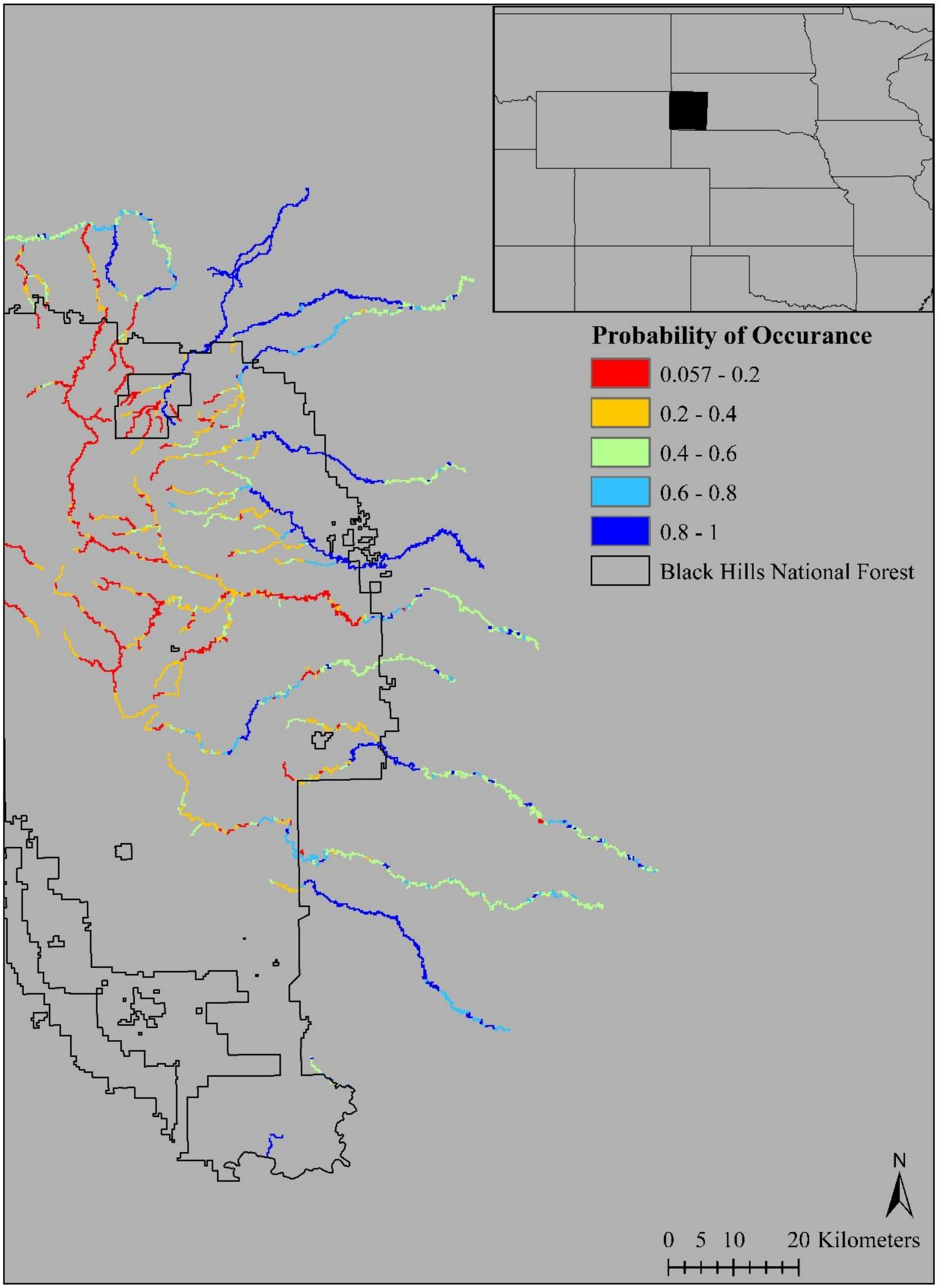

Figure 4. Ensembled model predictions for each stream surveyed during the 2014-2018 sampling period.

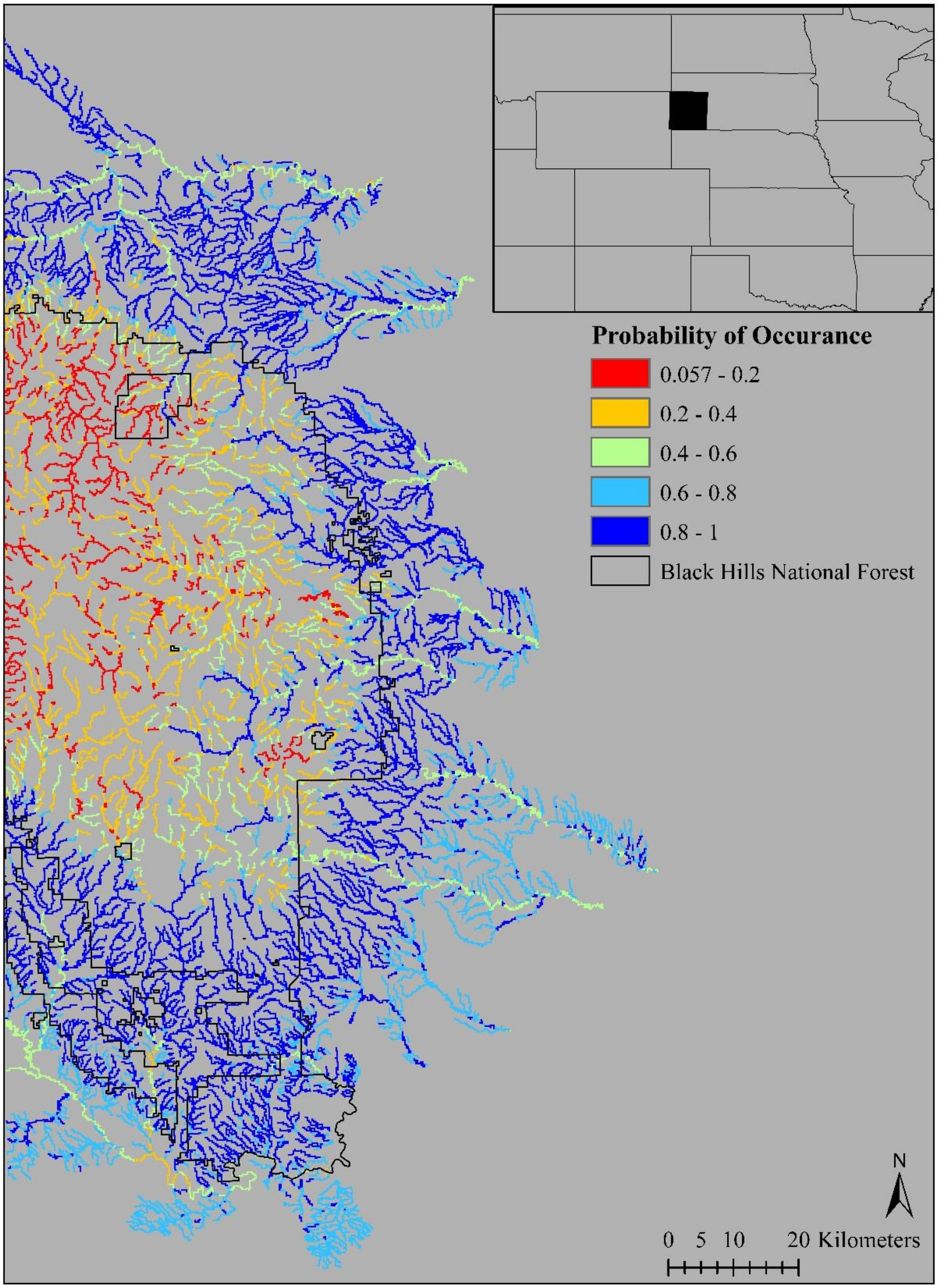

Figure 5. Ensembled model predictions for the entire Black Hills stream network.

CHAPTER SIX

TRENDS IN DISTRIBUTION AND DENSITY OF MOUNTAIN SUCKER *PANTOSTEUS JORDANI* IN THE BLACK HILLS OF SOUTH DAKOTA

ABSTRACT

Anthropogenic influences have hastened the imperilment of North American freshwater species over the past century. Local extirpations and species extinction rates are expected to increase into the future. Understanding population trends is essential to guide conservation management efforts for all species. Mountain Sucker, *Pantosteus jordani*, is native to the cold-water streams of the Intermountain west of North America and is listed as an indicator of biologic health in the Black Hills National Forest of South Dakota and Wyoming. South Dakota recognizes Mountain Sucker as a Species of Greatest Conservation Need. Recent studies indicated significant declines in both distribution and abundance of this species in the South Dakota portion of the Black Hills following a severe drought in the early 2000s. We assessed recent trends in Mountain Sucker density over the past 25 years using stream survey data for comparison with the previous study. Trends in abundance were insignificant at most sampling locations. Mountain Sucker distribution appeared to have expanded since the last study although local extirpations were observed in Annie Creek, Battle Creek, Rapid Creek below Pactola Dam, and Strawberry Creek. Translocation can be an effective management strategy for conserving regionally imperiled species. Our study identifies the current distribution of a regionally imperiled native fish, current trends in distribution, and areas where translocation could be applied as a conservation management strategy.

INTRODUCTION

North America is home to the greatest freshwater biodiversity on earth including numerous aquatic invertebrates and over 1,100 native fish species (Abble et al. 2000, Jelks et al. 2008). In the United States alone, recreational fisheries accounted for over $100 billion in economic impacts during 2011 (Hughes 2015). Despite the clear biological and recreational importance, aquatic ecosystems are one of the most threatened environments across North America. Observed extinction rates, per decade, for freshwater fauna were greater than for any terrestrial or marine fauna at the turn of the century and were predicted to more than double over the next 100 years (Ricciardi and Rasmussen 1999).

Anthropogenic influences pose the greatest threats to freshwater ecosystems globally (Jelks et al. 2008). Aquatic ecosystems are subject to the cumulative impacts of anthropogenic influences. Alterations in aquatic connectivity, habitat, hydrologic patterns, water temperatures, and local species assemblages can all negatively impact aquatic biodiversity and health (Dudgeon et al. 2006, Helfman 2007). Monitoring the health of aquatic organisms can be used to indicate trends in ecological health (Leidy and Moyle 1998). Mountain Sucker, *Pantosteus jordani* (Unmack et al. 2014), has been identified as an indicator species in the Black Hills National Forest (BHNF) of South Dakota and Wyoming (SAIC 2005).

Mountain Sucker have been observed throughout the intramountainous west of North America with distributions ranging north to south from Alberta to Utah, and west to east from eastern California to the populations found in and around the BHNF of South Dakota and Wyoming.(Scott and Crossman 1973, McPhail 2007, COSEWIC 2010, Unmack et al. 2014). Mountain Sucker are considered to be secure throughout their collective range (NatureServe 2019), however peripheral populations have been shown to be in decline, including those found in the Black Hills (Moyle and Vondracek 1985, Patton et al. 1988, Decker 1989, Schultz and Bertrand 2012).

Mountain Sucker found within South Dakota are considered to be completely isolated from conspecific populations (Bertrand et al. 2016). Historically, Mountain Sucker were widely distributed throughout the complex, cold-water, stream network found throughout the Black Hills region (Bailey and Allum 1962). Schultz and Bertrand (2012) noted significant changes in local distributions and abundance of Mountain Sucker.

Local isolations between populations of Mountain Sucker are observed between Black Hills drainages due to a combination of anthropogenic and natural constraints (Bertrand et al. 2016). Changes in land use, mining activities and the fragmentation of streams due to the construction of civil and municipal structures have threaten stream-dwelling organisms throughout the Black Hills (Berry et al. 2007). Additionally, local populations are often isolated between watersheds due to area of surficial dewatering that encircles the Black Hills, generally referred to as the ‘loss zone’, thermal constrains associated with intermediate habitats watersheds and interspecific interactions with non-native species (Williamson and Carter 2001, Isaak et al. 2003, Belica and Nibbelink 2006, Dauwalter and Rahel 2008, Schultz et al. 2015). Directed management actions have been recommended to ensure long-term conservation of Mountain Sucker in the Black Hills (Belica and Nibbelink 2006, Dauwalter and Rahel 2008, Schultz and Bertrand 2012).

Translocations have been widely applied to aid in the conservation of imperiled species across the world (Griffith et al. 1989). Translocations can be defined as the human-mediated movement of living organisms from one area for release in another (ICUN/SSC 2013). Conservation directed translocations include the underlying goal of improving the conservation status of the organism being translocated and the restoration of natural ecosystems (ICUN/SSC 2013, Malone et al. 2018). Translocation guidelines are becoming more established and can be used to evaluate the feasibility of translocation as an effective conservation/management strategy (Griffith et al. 1989, Olden et al. 2010, ICUN/SSC 2013). Species translocations can be an efficient (minimizing cost and effort) conservation approach when highly abundant, local source populations are available (Griffith et al. 1989, Fischer and Lindenmayer 2000, Parker 2008) when compared to other conservation actions such as propagation and stocking (Malone et al. 2018). Local abundances of Mountain Sucker were shown to be in general decline across the Black Hills' stream network, but local populations in the northern Black Hills may be able to serve as sources for translocation efforts (Schultz and Bertrand 2012, Bertrand et al. 2016).

To inform management and conservation efforts the objective of this study was to evaluate current trends in local distribution and abundance of Mountain Sucker with findings made by Schultz and Bertrand (2012). Understanding current trends in distribution and density will inform the evaluation of translocation as a feasible management action for the conservation of Mountain Sucker in the Back Hills of South Dakota. Using available data, I provide a general framework for the translocation of Mountain Sucker in the Black Hills region.

METHODS

Study Area

The Black Hills of South Dakota and Wyoming represent a unique ecosystem within the sea of short to midgrass prairie (Berry et al. 2007). The dome-shaped uprising is composed of unique geological formations that attribute to the complexity of the cold-water stream network found within. The core of the 100km (east-west) and 200km (north-south) dome is composed of Precambrian metamorphic and intrusive formations and is surrounded by a ring of sedimentary formations from the Cretaceous period (DeWitt et al. 1989). The Black Hills are part of the Middle Rockies Ecoregion (Level III) and are characterized by dense stands of ponderosa pine (*Pinus ponderosa*), numerous, spring-fed streams of variable morphology, and open meadows (Omernik 1987, Schultz et al. 2015). Comparatively few streams are observed on the western edge of the Black Hills owing to the surrounding sedimentary formations serving as groundwater recharge zones; streams that originate in the center of the dome generally flow to the north and east whilst losing much-all of their surficial flow as they flow across the porous sedimentary formations resulting in ‘loss zones’ (Williamson and Carter 2001). Only three streams exhibit perennial flow through the loss zones Fall River, Whitewood Creek, and Rapid Creek.

Anthropogenic influences: fire suppression, grazing, mining, construction of dams and roads, habitat manipulations, and fisheries management, have had significant impacts on stream morphology, connectivity and assemblage in the Black Hills (Rahn et al. 1996, Brown and Sieg 1999, Hamilton and Buhl 2000, May et al. 2001, Berry et al. 2007, Schultz and Bertrand 2012, Bertrand et al. 2016). The assemblage of native stream-dwelling fish species found within the Black Hills includes Mountain Sucker, White

Sucker (*Catostomus commersonni*), Longnose Sucker (*Catostomus catostomus*), Creek Chub (*Semotilus atromaculatus*), and Longnose Dace (*Rhinichthys cataractae*). European settlement resulted in the addition of non-native salmonids, Brook Trout (*Salvelinus fontinalis*), Brown Trout (*Salmo trutta*) and Rainbow Trout (*Oncorhynchus mykiss*), to the stream network to provide recreational angling opportunities in the late 1800's (Berry et al. 2007). Introduced salmonids have been shown to dominate stream assemblages throughout the Black Hills and whilst providing a valuable fishery they have been shown to negatively impact populations of Mountain Sucker (Berry et al. 2007, Dauwalter and Rahel 2008, Schultz et al. 2015, Rowles et al. *Unpublished Data*).

Fish Sampling

We assessed historic Mountain Sucker density at sampling locations using data from South Dakota Department of Game Fish and Parks (SDGFP). We used 'recent' sampling records (1993-2013) to assess local trends in Mountain Sucker density (fish/m^2) across the Black Hills. To evaluate current distribution and abundance of Mountain Sucker we sampled fish at historically sampled locations (N=144) throughout the Black Hills (Figure 1, Schultz et al. 2015). All sites were sampled a minimum of two times during the sampling period (2014-2018). Sampling occurred during summer months (May-September) each year. Block nets were placed at the upstream and downstream ends of established 100 m sampling locations. Multi-pass depletion electrofishing was used to estimate abundance in each sampling location and was conducted using pulsed, direct current from backpack electrofishing units (Smith-Root models LR-24 and 12-B electrofishers, Vancouver, Washington; Zippin 1958, Bonar et al. 2009). This survey method has been demonstrated to be very effective for sampling Mountain Sucker even at low densities (Dauwalter and Rahel 2008). Following electrofishing efforts, captured fish were identified to species, counted, measured mm (total length), and weighed g, prior to release back into the sampling reach. Stream widths (n=11) were recorded at each sampling location to estimate total sampled area (m^2). If stream width was greater than 6 m, two backpack electrofishing units were used (Schultz and Bertrand 2012).

Analysis

We used a Mann-Kendall correlation test to examine trends in Mountain Sucker density, at historic sampling locations throughout the Black Hills (RCoreTeam 2019). Following Schultz and Bertrand (2012), we log-transformed density data prior to analysis. Our analysis was limited to locations where Mountain Sucker had been observed within the 2014-2018 sampling period and had been sampled at least five times during the 25 year period of interest (Table 1, Figure 1).

RESULTS

Our sampling (2014-2018) observed Mountain Sucker in 44 of 144 sampling locations covering a broad area across the region (Figure 1). Mountain Sucker appear to have been locally extirpated from several streams including Annie Creek, Battle Creek, and Crow Creek, since the last study (Schultz and Bertrand 2012). Our study also documented Mountain Sucker in several streams thought to be devoid of the species during the previous study: Fall River, French Creek, and Spring Creek. Several comparatively novel populations were observed in streams unsampled during the previous study including Flynn Creek, Slate Creek and the Redwater River. Large portions of several streams also appear to be locally devoid of Mountain Sucker: Rapid Creek below Pactola Dam, Castle Creek Above Deerfield Reservoir, Spearfish Creek, and Whitewood Creek above Deadwood. The core of Mountain Sucker distribution still appears to be in the northern half of the Black Hills.

Mountain Sucker densities varied between stream and sampling locations (Figure 1). Mean Mountain Sucker densities at sampling locations ranged from 0.0025-0.748 fish/m^2 with about half of the locations (n = 21) exhibiting mean densities <0.01 fish/m^2. The highest mean densities of Mountain Sucker >0.3 fish/m^2 were observed at two locations in Whitewood Creek where the stream transitions from the mountainous hills to the prairie. Few temporal trends in density were observed for locations of Mountain Sucker occurrence in this study. Historic data (1993-2018) with at least five observations was available for 35 sampling locations (Table 1). A significant decrease in Mountain Sucker density ($\tau = 0.53$, $P < 0.05$) was detected at one sampling location in Whitewood Creek. For the remaining sampling locations (n=34) no significant trend ($P > 0.05$) in local Mountain Sucker density was detected (Table 1).

DISCUSSION

Mountain Sucker exist in varying densities across their local range with the highest densities being observed Whitewood Creek. Mountain Sucker were observed in 16 different streams across the Black Hills with most populations occurring in the northern Black Hills. Schultz and Bertrand (2012) did not observe Mountain Sucker in southern portion of the region and predicted local extirpation in that portion of the Black Hills. We observed Mountain Sucker in three southern Black Hills streams: Fall River, Flynn Creek and French Creek.

Established populations of Mountain Sucker in the Black Hills of South Dakota have remained relatively stable over the past 25 years. Our 25 year period of interest should be sufficient to detect trends in Mountain Sucker density (Dauwalter et al. 2009). Significant trends in density were observed in three locations (Table 1). More extreme trends in Mountain Sucker densities may not have been observed due to the removal of sampling locations owing to a lack of recent survey data. Several locations assessed in the previous study (Schultz and Bertrand 2012) were not included in our analysis due to the absence of Mountain Sucker during the 2014-2018 sampling period including locations in Annie Creek, Battle Creek, Rapid Creek below Pactola Dam, and Strawberry Creek. Our analysis did include sites located in 11 streams not included in the previous study. The ability to include these additional sites likely contributed to the increased detections associated with sampling novel locations and increased sampling effort (MacKenzie et al. 2005).

Newly identified populations of Mountain Sucker were likely present during the previous study but went undetected at that time. Mountain Sucker populations in the Black Hills exist in relative isolation to their conspecifics. A combination of factors including disjunct connectivity (Williamson and Carter 2001), minimal movement distances (Chapter 2), thermal restrictions associated with the prairie (Schultz and Bertrand 2011), and influences of non-native salmonids (Figure 2) make it unlikely that recolonization occurred since the previous study (Dauwalter and Rahel 2008, Schultz and Bertrand, 2012, Schultz et al. 2015, Rowles et al. *Unpublished Data*).

Schultz and Bertrand (2012) identified three confounding factors associated with their study, including the potential for bias against non-game species during historic sampling events, limited information regarding Mountain Sucker movement patterns, and limitations of only sampling historic locations. We addressed these limitations by conducting a more robust survey over an extended period (5 years) to monitor recent trends in Mountain Sucker occurrence. Our 25-year period of interest included data from 2 studies specifically targeting Mountain Sucker minimizing the potential bias of population estimates generated for non-target (often non-game) species (Zalewski and Cowx 1990). Mountain Sucker have been shown to exhibit variable intra-seasonal movement (Decker and Erman 1992); however, Mountain Sucker in the Black Hills did not exhibit large-scale movements needed to recolonize neighboring streams (Chapter 2). Additionally, genetic analysis in the region indicated low probability that inter-stream mixing of genetics had occurred within the last 100 years (Bertrand et al. 2016). Finally, our study design incorporated sites sampled in the previous study, historic stream monitoring, and novel sampling locations, yielding previously unobserved populations of Mountain Sucker.

Despite the relative stability of Mountain Sucker densities observed for our period of interest, a significant negative trend was still observed at one location. This location occurs far onto the prairie where increased stream temperatures could limit the suitability of the local habitat (Chapter 2). Mountain Sucker were not observed in three streams where they had previously been documented (Schultz and Bertrand 2012), indicating that trends in distribution and abundance are still negative at multiple locations not included in this analysis. Variation in local population trends has been previously observed for Mountain Sucker in the Black Hills (Belica and Nibbelink 2006). Although region-wide intervention may not be needed to maintain this species in the region, local conservation efforts are likely required to restore this species to its’ historic, regional distribution.

Risk assessments for Mountain Sucker in the Black Hills identified: changes in land use (habitat degradation), climate change (increased stream temperature and dewatering), introduced salmonids (predation), and habitat fragmentation as the primary threats to Mountain Sucker (Isaak et al. 2003, Belica and Nibbelink 2006). While significant changes in land use and management are unlikely to rapidly change, opportunities exist to incorporate conservation efforts into the current management strategy. Several actions have been suggested for the conservation of Mountain Sucker in the Black Hills including translocation, habitat restoration, and removal of non-native species (Schultz and Bertrand 2012). Translocation has been a widely applied conservation action for imperiled, lotic species (Minckley 1995). Barred Galaxias (*Galaxias fuscus*) were successfully translocated into portions of their historic range in New Zealand (Ayres et al. 2009). In the Colorado River basin over 900 Humpback Chub (*Gila cypha*) were translocated into an adjoining tributary to expand the species distribution in the area.

Translocation success can be increased with the consideration of both biological and physical factors that may contribute to the survival of both the source and translocated populations (George et al. 2009). Malone et al. (2018) considered habitat, genetics and abundance estimates when evaluating the reintroduction potential of three candidate fish species in the Great Smoky Mountains National Park. Species were selected based on their historic distribution in the area, the proximity of local source populations and their role in promoting broader ecological health, primarily through known interactions with native mussels. Accounting for habitat variables and stocking variables has been shown to increase the likelihood of translocation success.

Additionally, the presence of non-native species was correlated with translocation failure (Cochran-Biederman et al. 2014). Non-native salmonids provide a popular recreational fishery across the Black Hills region (Figure 3) though it is likely that translocation success would be limited in areas where trout currently occur. As with all management effort local support is essential to maximize the effectiveness of management efforts (Decker et al. 1996).

Opinion surveys across the region indicated general support for management strategies that include the active management of native, non-game fish in the region (Chapter 3). Mountain Sucker have been shown to associate closely with a variety of segment and local scale habitat characteristics. Course substrates, overhead cover (vegetative, large woody debris, undercut banks, etc.), increased periphyton, stream permanency, and stream temperature have been related to the presence of Mountain Sucker (Decker 1989, Dauwalter and Rahel 2008, Schultz et al. 2015, Chapter 5). Negative interactions between Mountain Sucker and non-native salmonids (primarily Brown Trout) have been documented in the region (Dauwalter and Rahel 2008, Schultz et al. 2015, Rowles et al. *Unpublished Data*). Areas devoid of Mountain Sucker, with appropriate habitat, and lacking in adult trout could serve as potential locations to focus preliminary translocation efforts (Figures 1-3, Table 2).

The identification of source populations is essential for species translocation. The most robust populations of Mountain Sucker are found in Whitewood Creek (Figure 1) and it is likely that these locations could serve as source locations for preliminary translocation efforts. Genetic assessment of regional Mountain Sucker collected from Annie, Whitewood, Bear Butte, Elk, Boxelder and Rapid Creeks indicated that although genetic drift was evident between streams gene flow had likely occurred between streams in close proximity within the past century (Bertrand et al. 2016). To maintain the genetic diversity of Mountain Sucker within the Black Hills Bertrand et al. (2016) recommended 1) increasing the number of streams containing Mountain Sucker, and 2) increasing abundance of Mountain Sucker in occupied streams. Using Mountain Sucker from local source locations will aid in the preservation of the genetics of this peripheral population.

Both source locations and translocation sites should be monitored closely before and after translocation efforts to assess potential impacts on the source population and success/failure of translocation efforts (Cochran-Biederman et al. 2014). Successful translocations can require a variable number of fish to be taken from the source population. Ayres et al. (2009) were able to successfully translocate Barred Galaxias into two separate stream reaches during trial translocation efforts using a total of 90 adults (50:40 split). I recommend following a similar approach and propose that that 50 Mountain Sucker are taken via electrofishing from each of the three most abundant Mountain Sucker sources (Table 1, Figure 1) for translocation into stream reaches devoid of adult Brown Trout (Figures 2-3).

Areas devoid of Brown trout where recent extirpation events have occurred could serves as initial locations for preliminary translocation efforts (Table 2). The supplemental translocation of fish into locations with low densities (i.e. Slate Creek and French Creek populations) could help ensure the long-term survival of locally disjunct populations. Streams with unutilized salmonid fisheries (i.e. Battle Creek and Iron Creek South) could also serve as areas for translocation efforts if effort were taken to reduce abundance or completely remove trout from the stream prior to translocation efforts.

Model predictions (Chapter 5) indicated increased probability of Mountain Sucker occurrence in streams around the periphery of the Black Hills. These areas could also be considered for translocation efforts if suitable local-scale habitat conditions are present.

Ideally translocation will consist of mature Mountain Sucker (>100 mm total length) prior to spawning to maximize the potential for spawning once stocked into the translocation site (Hauser 1969, Wydoski and Wydoski 2002, Breeggemann et al. 2014). Mountain Sucker spawn in the spring (Decker and Erman 1992, Wydoski and Wydoski 2002) with maximum spawning activity occurring in late May-early June in the Black Hills (Fopma, *Unpublished data*).

Translocated fish should be marked prior to release and monitored regularly post-release to assess the success/failure of the translocation effort (George et al. 2009). It is likely that multiple translocations will be needed to reestablish Mountain Sucker in each location and I recommend translocating fish to each location for at least four consecutive years to increase the probability of success. Consistently monitoring translocated populations will allow managers to identify causative conditions that result in the success of the translocation. In addition to monitoring the translocated population, regular assessment of local habitat conditions will aid in evaluating translocation success. The success of a translocation effort is largely dependent upon the goals of the management agency; however, I consider a successful translocation as one that results in the establishment of a naturally recruiting population.

MANAGEMENT IMPLICATIONS

Translocation can be a cost-effective management option when local habitat characteristics and the access to local source populations are available (Griffith et al.

1989, Fischer and Lindenmayer 2000, Parker 2008). Schultz and Bertrand (2012) and the current study suggests that Mountain Sucker density and distribution have declined significantly across the Black Hills Region of South Dakota compared to historic levels (Bailey and Allum 1962). Despite the long-term declines across the region, our study suggested that Mountain Sucker densities have been comparatively stable over more recent years with few exceptions at both the local and stream level. Repatriation and supplementation of populations via translocation could be an effective conservation strategy for this species in areas where it has been locally extirpated or diminished. We identify several areas where trial translocation efforts could be conducted in the absence of adult trout populations. In addition to continued monitoring of known populations of Mountain Sucker, an increase in monitoring of randomly selected sites is needed to more accurately assess current distribution. Trial translocation efforts should be closely monitored to inform any future or large-scale conservation actions.

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Table 1. Mann-Kendall analysis of Mountain Sucker density (log(fish/m2) for the years 1993-2018 at sampling locations in the Black Hills of South Dakota. N = the number of times the site was sampled during the 25-year period. Density = mean density of Mountain Sucker observed during the 2014-2018 sampling period.

Sample Location	N	$\lvert\tau\rvert$	*P*	Density
Bear Butte 44.334N, -103.625W	11	0.343	0.18	0.0015
Bear Butte 44.298N, -103.676W	6	0.2	0.71	0.0186
Bear Butte 44.307N, -103.669W	8	0.161	0.69	0.0136
Boxelder Creek 44.157N, -103.466W	8	0.47	0.2	0.0053
Boxelder Creek 44.229N, -103.599W	7	0.49	0.17	0.0192
Boxelder Creek 44.198N, -103.535W	5	0.4	0.46	0.0806
Castle 44.078N, -103.718W	6	0.18	0.82	0.0005
Elk Creek 44.277N, -103.696W	6	0.64	0.12	0.0317
Fall River 43.403N, -103.412W	6	0.79	0.051	0.0043
Fall River 43.419N, -103.458W	6	0.26	0.65	0.0064
Flynn Creek 43.685N, -103.473W	7	0.19	0.65	0.1589
Jim Creek 44.146N, -103.504W	5	0.32	0.72	0.0020
Jim Creek 44.146N, -103.550W	7	0.12	0.87	0.0060
Meadow 44.294N, -103.560W	6	0.12	0.99	0.0016
Middle Boxelder 44.198N, -103.700W	6	0.12	0.99	0.0052
North Fork Rapid 44.132N, -103.736W	7	0.35	0.36	0.0042
North Fork Rapid 44.197N, -103.761W	6	0.6	0.13	0.0476
North Fork Rapid 44.178N, -103.756W	5	0.4	0.46	0.0852
Rapid 44.121N, -103.709W	8	0.05	0.99	0.0006
Rapid 44.111N, -103.671W	5	0.11	0.99	0.0005
Redwater River 44.580N, -104.017W	6	0.12	0.99	0.0018
Slate 44.032N, -103.634W	7	0.28	0.56	0.0014
Spring 43.944N, -103.513W	6	0.09	0.99	0.0006
Swede 44.178N, -103.777W	7	0.27	0.53	0.0120
Swede 44.174N, -103.799W	14	0.26	0.15	0.0103
Whitewood 44.621N, -103.472W	10	0.36	0.22	0.0013
Whitewood 44.385N, -103.719W	18	0.13	0.49	0.0475

Whitewood 44.412N, -103.694W	18	0.09	0.63	0.2179
Whitewood 44.460N, -103.620W	10	0.53	0.054	0.7484
Whitewood 44.366N, -103.734W	15	0.03	0.92	0.0044
Whitewood 44.474N, -103.627W	11	0.21	0.44	0.1070
Whitewood 44.518N, -103.608W	17	0.05	0.83	0.549
Whitewood 44.622N, -103.471W	15	0.11	0.63	0.0003
Whitewood 44.589N, -103.520W	14	**0.53**	**0.016**	0.0077
Whitewood 44.396N, -103.703W	6	0.2	0.71	0.1316

Table 2. Location, elevation (m) stream order (Strahler 1957),mean stream width (m), mean substrate size (mm), mean substrate periphyton coverage (%) and mean canopy coverage for potential trial Mountain Sucker translocation efforts.

Sample Location	Elevation	Perennial	Stream Order	Stream Width	Substrate Size	Periphyton Coverage	Canopy Cover
Annie Creek 44.331, -103.878	1657		3	2.3	95	8	73
Burno Gulch 44.4272, -103.839	1426	x	3	2.9	109	17	64
Strawberry Creek 44.323, -103.652	1524	x	3	1.6	57	19	75

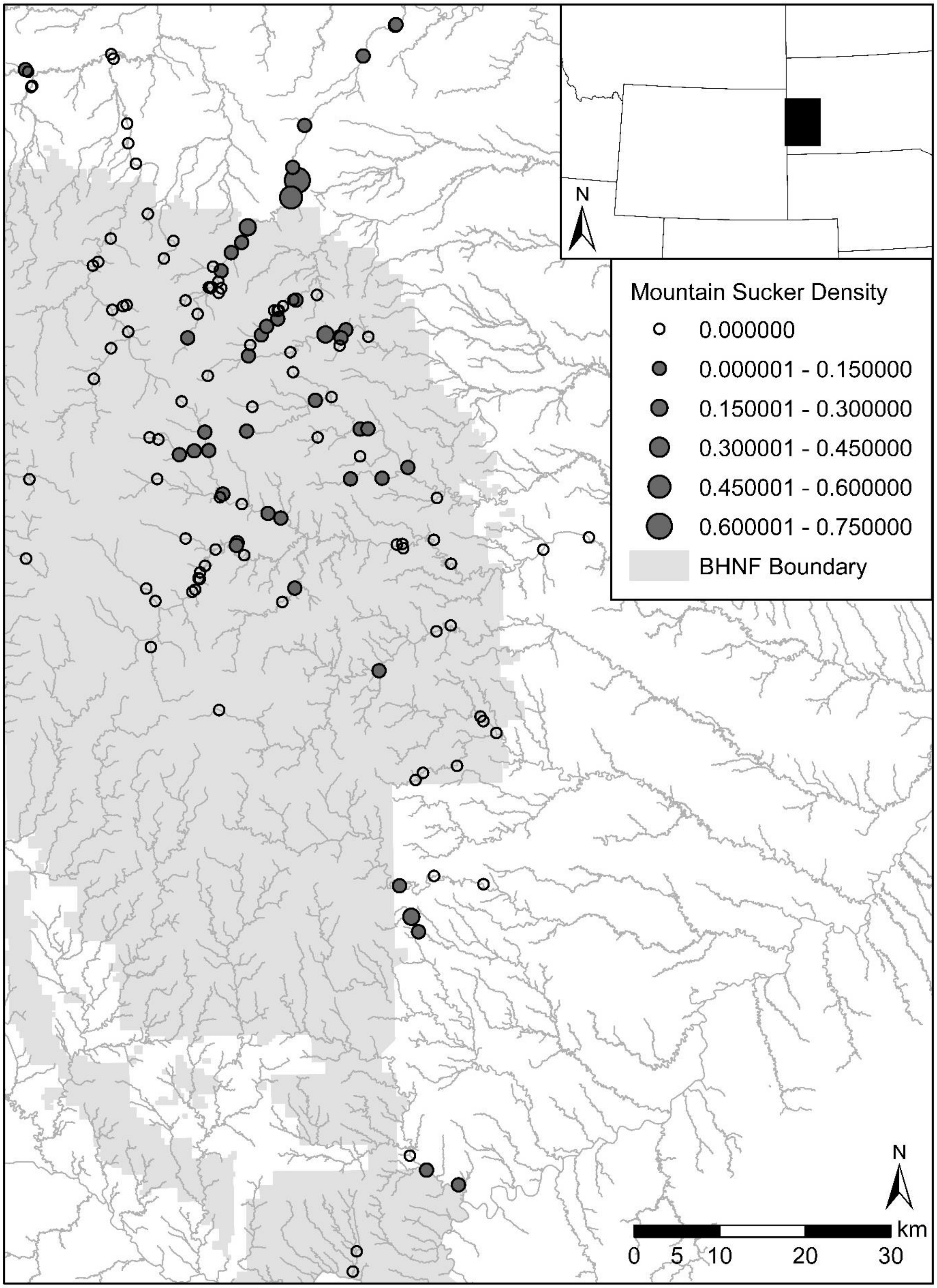

Figure 1. Mean density (fish/m^2) of Mountain Sucker at locations sampled during the 2014-2018 study period.

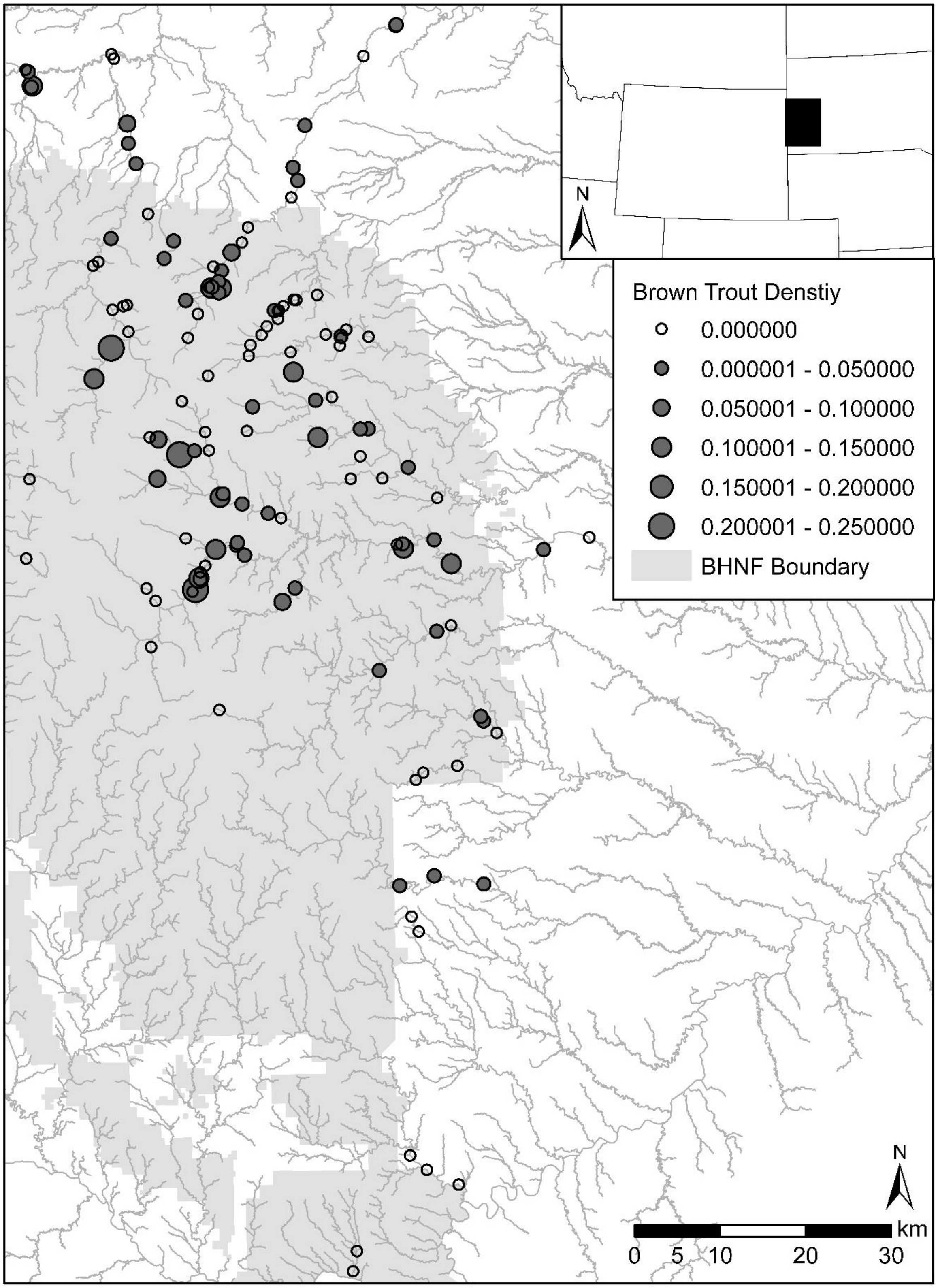

Figure 2. Mean density (fish/m^2) of adult (>200 mm) Brown Trout at locations sampled during the 2014-2018 study period.

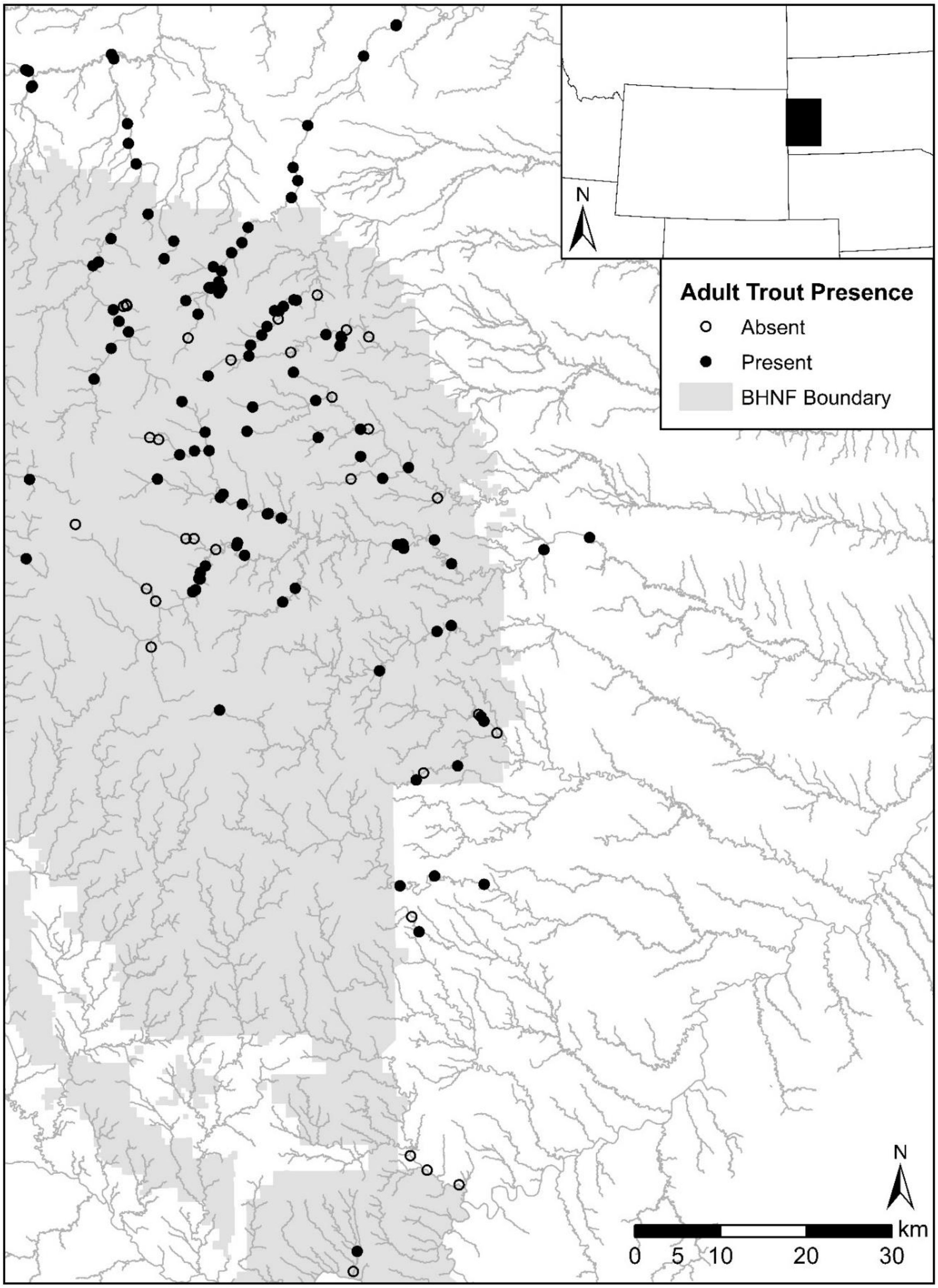

Figure 3. Distribution of adult trout (>200 mm total length) in the Black Hills of South Dakota.