U.S. Department of the Interior
National Park Service
Yellowstone Center for Resources
Fisheries and Aquatic Sciences Program
P.O. Box 168
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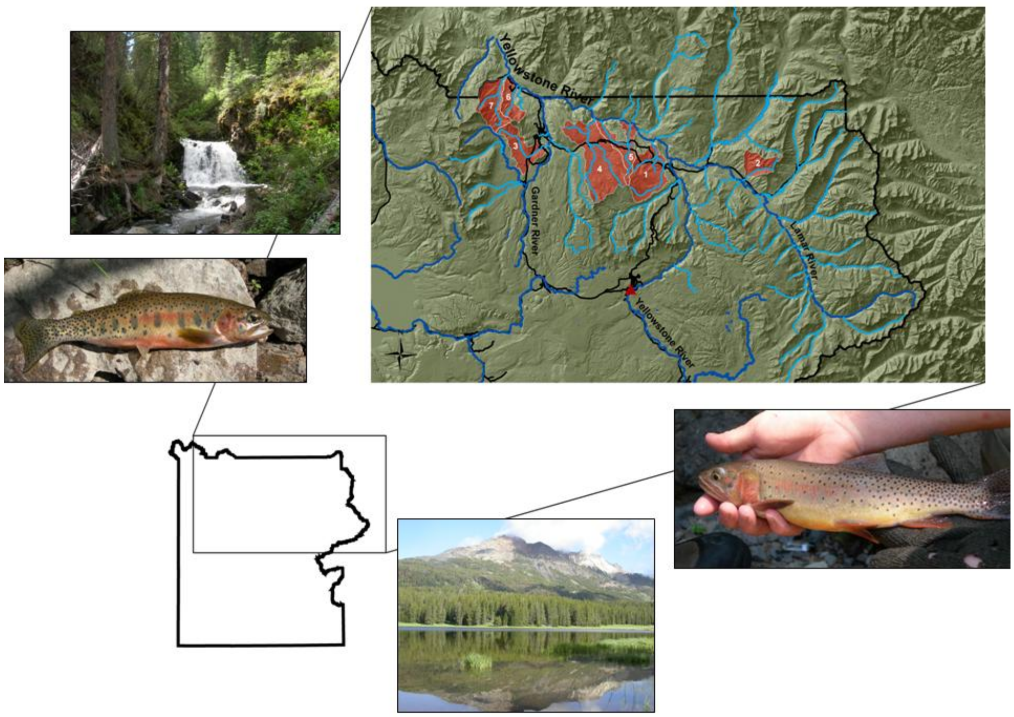
Cutthroat Trout Restoration Across Yellowstone's Northern Range



Phase I
Completion Report
YCR-2007-05

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30 September 2007

Suggested citation:
Ruhl, M.E. and T.M. Koel. 2007. Cutthroat trout restoration across Yellowstone's Northern Range: Phase I completion report. National Park Service, Yellowstone Center for Resources, Fisheries & Aquatic Sciences Program, Yellowstone National Park, Wyoming, YCR-2007-05.

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EXECUTIVE SUMMARY

Growing concern regarding the status of Yellowstone cutthroat trout (*Oncorhynchus clarki bouvieri)* within Yellowstone Lake has led park managers to investigate the potential for restoration of this subspecies to park waters outside of the Lake basin, and in particular, across the park's Northern Range. These investigations are focused on both improving our understanding of the current status and distribution of Yellowstone cutthroat trout and on reversing the trend of loss of genetically pure Yellowstone cutthroat trout in these areas, through the planning and eventual implementation of restoration actions.

This report summarizes results of initial data compilation/collection and watershed prioritization completed during Phase I of the effort to restore cutthroat trout across the Northern Range of Yellowstone National Park. In compiling this report a review of historical records was conducted and used to identify data gaps and sampling needs. The data compiled during the review of historical records and through recent field sampling (2005 – 2007) have been incorporated into a northern range streams database which now contains information pertinent to determining the restoration potential of Northern Range streams. Categories of information used in this prioritization process included species composition, genetic integrity, presence/absence of barriers, road and trail access, interpretive value, watershed complexity, and other factors. This information was then used to create a prioritization matrix designed to rank each stream based on its potential for successful restoration.

The streams that ranked highest, in terms of probability for success in future restoration efforts, included Elk, Yancey, Lost, and Rose creeks. As the Northern Range cutthroat trout restoration effort moves forward, the completion of state and federal documentation and permitting, including completion of a NEPA process will be required in order to undertake on-the-ground restoration activities. This process will represent Phase II and is expected to begin soon. Completion of the NEPA compliance and other state and federal permitting could allow initiation of Phase III of this effort, which specifically is the removal of nonnative fishes and subsequent establishment of genetically-pure Yellowstone cutthroat trout populations.

INTRODUCTION

The waters of Yellowstone Lake and the Yellowstone River upstream of Canyon are home to the last stronghold of Yellowstone cutthroat trout (*Oncorhynchus clarki bouvieri*; YCT). In the face of widespread introductions of nonnative salmonids into many other park waters, this system has avoided the establishment of nonnative species, such as rainbow trout (*O. c. mykiss*) known to hybridize and cause a permanent loss of genetic integrity of the YCT population. However, the discovery of nonnative lake trout (*Salvelinus namaychus*) and whirling disease (caused by the exotic parasite *Myxobolus cerebralis*) within Yellowstone Lake in 1994 and 1998, respectively, have left the future of YCT here in question.

The nonnative and exotic species threats to YCT within Yellowstone Lake and the uncertainty of the subspecies' future there resulted in a need to ensure the persistence and/or improve the status of genetically pure YCT elsewhere within Yellowstone National Park, including waters of the Northern Range. As a part of the Yellowstone River watershed within the park, the Northern Range is comprised of several sub-watersheds including the lower Yellowstone, Lamar, and Gardiner rivers (Figure 1). Contained within these sub-watersheds are over fifty named streams and hundreds of unnamed tributaries.

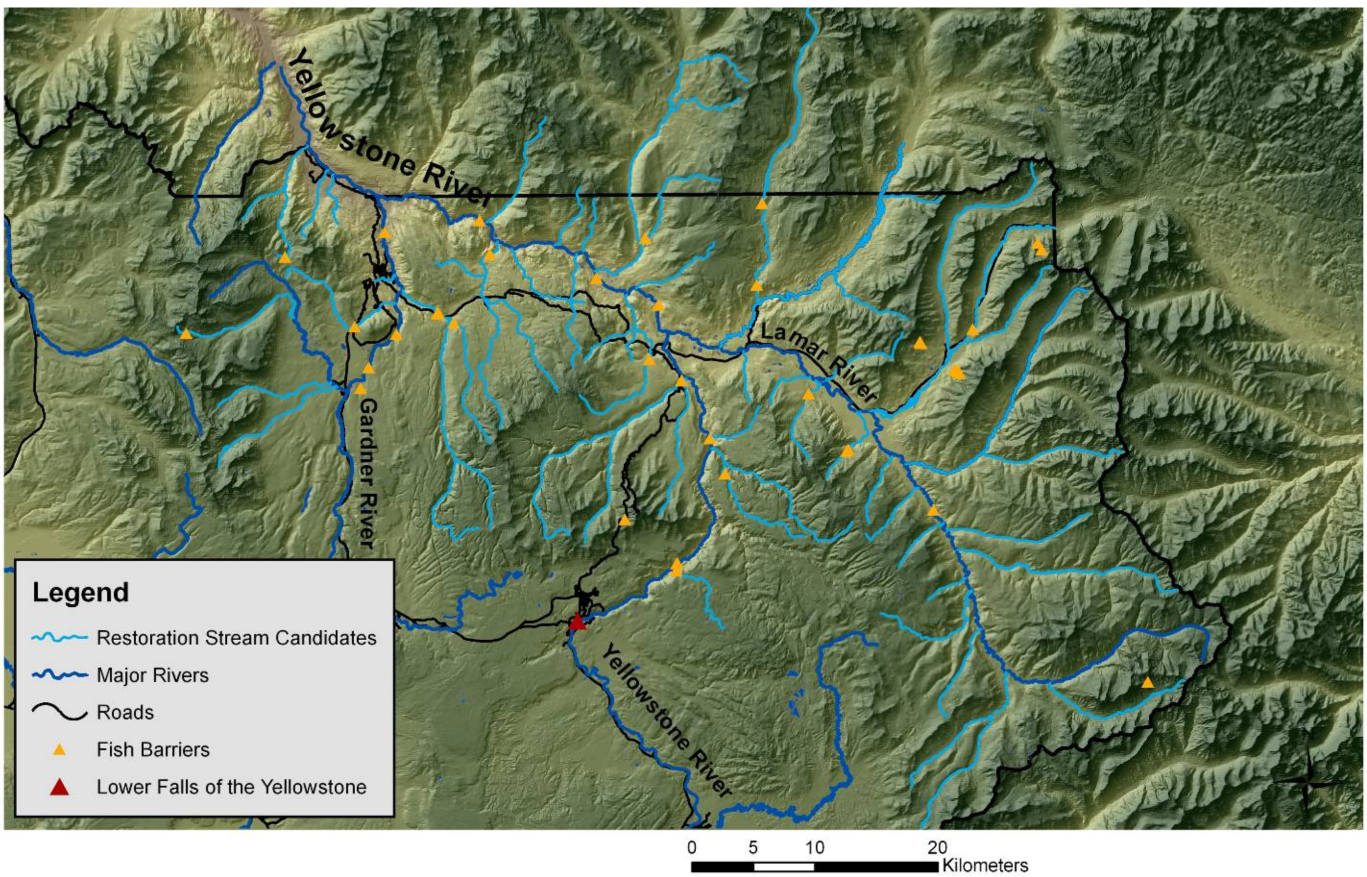

Figure 1. Yellowstone's Northern Range including rivers and streams under consideration for restoration.

Yellowstone's Northern Range represents a large geographical area that was once (almost solely) home to genetically-pure YCT. Fish propagation and "planting" efforts that began in the late-1800s, however, resulted in the introduction of several nonnative fish species into the Northern Range (Varley and Schullery 1998). These introductions resulted in an alteration of the distribution, abundance, and genetic integrity of YCT in the region. Introduced populations of brook trout *Salvelinus fontinalis* and brown trout *Salmo trutta* competed with YCT, and significantly altered historic populations. Even more detrimental, rainbow trout hybridized with YCT, thereby compromising genetic integrity.

Most stocking of nonnative salmonids occurred as part of official efforts to expand angling opportunities in the park by establishing fish populations in historically fishless waters and supplementing existing fisheries with hatchery stock. Stocking, for angling purposes, ended in the mid 1950's due to a paradigm shift in management, which resulted in less emphasis on consumptive angling and a greater emphasis on native species preservation. By the time stocking ended, however, millions of nonnative fish had been planted in waters across the park (Varley 1981). Invasion of pure populations from outside sources also was (and remains) a threat. Slough Creek, an important fishery in the Lamar River drainage that tested genetically pure in the mid-1990's, is now genetically compromised by RBT entering the system from an unknown source (Janetski 2006).

Thanks to the *Fisheries Fund Initiative* of the Yellowstone Park Foundation, Yellowstone National Park was able to begin an aggressive program in 2005 that will result in restoration of historic YCT populations across the parks' Northern Range. The restorations are expected to be accomplished through completion of these three phases (Figure 2):

Phase I.- Historical data collection, field sampling, and stream prioritization.
Phase II.- Completion of a NEPA process; federal and state permitting.
Phase III.- On-the-ground YCT restoration across the Northern Range.

This report represents completion of Phase I. However, the three work phases will occur, to some degree, concurrently because of the potential to discover additional historical records or derive new information through continuing field investigations. As this occurs, the information will be used to periodically update our database and, potentially, our approach to YCT restoration.

Our specific objectives for the Phase I work include, for all named streams across the Northern Range:

I. Reviewing the historical literature and creating a database containing physical, chemical, biological, logistical, and other anthropogenic information.
II. Conducting intensive field investigations to rectify data gaps identified by the historical review and updating the restoration database.
III. By considering multiple factors, prioritize streams based on their potential for successful YCT restoration.

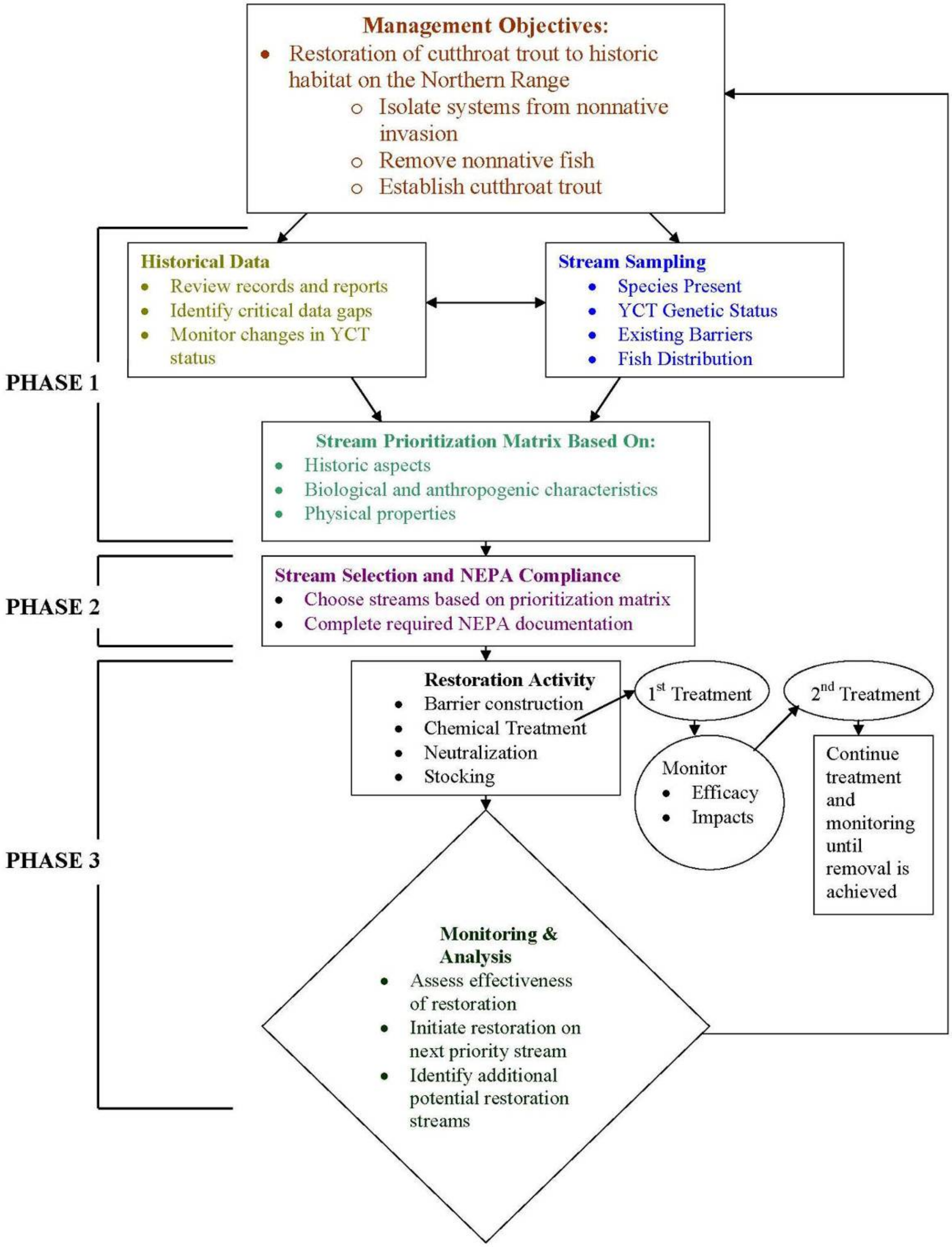

Figure 2. Conceptual model of Yellowstone cutthroat trout (YCT) restoration on the Northern Range of Yellowstone National Park.

Major sources of data include historical reports, sampling records and the modern Geographic Information System (GIS) database available through the Yellowstone Center for Resources. The literature review and field investigations seek to answer four primary questions about each stream, including: 1) What species, if any, are present in the stream? 2) What is the genetic status of any cutthroat trout populations found within the stream? 3) What is the extent of fish distribution in the watershed? 4) Are any existing or potential barriers to upstream fish movement present in the system?

This report reviews the precedent for native fish restoration in Yellowstone and other National Parks, outlines our methods for data collection from historic records and recent field sampling, describes the creation of a prioritization matrix for potential restoration streams, and provides results of investigations of streams with high restoration potential. Issues encountered while creating the prioritization matrix and about the realities of initiating native fish restoration projects are also discussed in this report.

BACKGROUND

Yellowstone National Park and Native Species Restoration

Yellowstone National Park encompasses 2,221,772 acres (3,472 square miles) and is located primarily in the northwest corner of Wyoming with portions extending into southwestern Montana and southeastern Idaho. It is the core of the Greater Yellowstone Area (GYA), an approximately 12 million-acre area that includes Grand Teton National Park and John D. Rockefeller, Jr. Memorial National Parkway to the south, seven national forests, three national wildlife refuges, three Native American Indian reservations, state lands, towns and private property.

By an Act of Congress on March 1, 1872, Yellowstone was "dedicated and set apart as a public park or pleasuring ground for the benefit and enjoyment of the people" and "for the preservation from injury or spoliation, of all timber, mineral deposits, natural curiosities, or wonders . . . and their retention in their natural condition." As the world's first national park, Yellowstone:

- preserves geologic wonders, including the world's most extraordinary collection of geysers and hot springs and the underlying volcanic activity that sustains them;
- preserves abundant and diverse wildlife in one of the largest remaining intact wild ecosystems on earth, supporting unparalleled biodiversity;
- preserves an 11,000-year-old continuum of human history, including the sites, structures, and events that reflect our shared heritage; and
- provides for the benefit, enjoyment, education and inspiration of this and future generations.

The NPS Organic Act of 1916 states that the NPS will "...conserve the scenery and the natural and historic objects and the wildlife therein and...provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations" (NPS Organic Act 16 U.S. Code 1). The park is managed to conserve, perpetuate, and portray as a composite whole the indigenous aquatic and terrestrial fauna and flora, the geology, and the scenic landscape.

Sport fishing has a historical precedent in Yellowstone, and has been a major visitor activity in the park for over 100 years. Yellowstone supports some of the world's most famous fisheries, and has been a destination for generations of anglers for over a century. However, as Yellowstone park managers have witnessed and science has clearly demonstrated, nonnative species introductions from the late 1889s through the mid-1900s resulted in the degradation (through hybridization) and loss of native cutthroat trout (*Oncorhynchus clarki* spp.) as well as native fluvial Arctic grayling (*Thymallus arcticus*).

The NPS 2006 Management Policies, section 4.4.2, directs that all exotic (i.e., nonnative) species that are not maintained to meet an identified park purpose will be managed—up to and including eradication—if: 1) control is prudent and feasible; and 2) the nonnative species interferes with natural processes and the perpetuation of natural features, native species, or natural habitats. Section 4.4.2 also calls for the restoration of native animals when adequate habitat to support the species exists or can be reasonably restored. Conservation of stream communities and native cutthroat trout and controlling nonnative aquatic species was identified as a high-priority need in Yellowstone's Resource Management Plan (NPS 1998).

The National Park Service and Native Fish Restoration

Artificial fish barriers constructed to prevent the upstream movement of nonnative/hybridized fish species and protect headwater populations of imperiled, native fish species have been used successfully in many locations, including several national parks (Thompson and Rahel 1998, Novinger and Rahel 2003, Shepard in press). Within national parks, the structures allow for the isolation and protection of native fishes in the absence of natural barriers to fish movement (waterfalls). This greatly increases the available options and overall probability of success for native fish restoration projects. It also ensures that historically fishless waters, usually located above waterfalls (and outside of the historical range of the species), are not the only habitats available to managers considering native fish restoration projects.

Within Crater Lake National Park, a barrier was constructed on Sun Creek to isolate a native bull trout (*Salvelinus confluentus*) population threatened by nonnative eastern BKT located downstream (Buktenica in press). Within Rocky Mountain National Park, fish barriers have been constructed for preservation/restoration of native greenback cutthroat trout (*O. c. stomias*; Stevens and Rosenlund 1986, USFWS 1998) and Colorado River cutthroat trout (*O. c. pleuriticus*; Rosenlund et al. 2000). More recently in Glacier National Park, a barrier was constructed on Quartz Creek to prevent the upstream movement of nonnative lake trout into the Quartz Lake chain of lakes, waters that are considered a last stronghold for bull trout in the park (B. Michels, Glacier National Park, personal communication 2006). In addition, artificial barriers have been used to manage other fish species in many other locations across North America. For example, 52 tributaries to the Great Lakes in Canada and 19 tributaries in the United States have fish barriers in place to prevent the upstream movement and subsequent spawning of nonnative sea lamprey (*Petromyzon marinus*) (University of Guelph 2002, Dodd et al. 2003).

Precedent for construction of fish barriers to prevent upstream movement of nonnative fish and/or isolate and protect headwater native fish populations has been set. This method, at present, represents the best available technology for preventing invasion by nonnative/hybridized fishes into a restoration area, especially one that is located in a remote, backcountry location. In instances where native cutthroat trout are immediately threatened by nonnative fish species, research has shown that isolation by artificial barrier construction may be the only alternative (Novinger and Rahel 2003). Measurements made on a study of 47 stream tributaries to the Great Lakes indicated that small, low-head fish barrier structures did not significantly alter stream habitats, although they may create habitat that either favors certain species or provides refuge from predators (University of Guelph 2002, Dodd et al. 2003). No comparative studies have been conducted on effects of fish barriers to stream habitats in the Intermountain West.

Precedent for the use of piscicides (fish toxicants) in native fish restoration and conservation actions in national parks has also been established. An on-going program to restore BKT to their native waters in Great Smokey Mountains National Park utilizes the piscicide Antimycin-A to remove nonnative RBT (Moore et al 2005). Piscicides have also been used several times in Yellowstone, most notably to remove introduced Yellowstone cutthroat trout from High Lake (within the range of westslope cutthroat trout; Koel et al. 2007), and remove nonnative brook trout from Arnica Creek, a tributary to Yellowstone Lake, in 1985 and 1986 (Greswell 1991). Crater Lake, Rocky Mountain, and Great Basin National Parks have also used chemical fish toxicants to restore native fishes to park waters (Buktenica In press, Darby et al 2004, Roselund et al 2000). Moore et al. (2005) found that chemical piscicides were both the only way to reliably achieve a complete removal of nonnative fishes from a wide range of stream sizes and are also more cost effective than mechanical removal methods.

METHODS

Literature Review

Fisheries management activities, including fisheries inventories and sportfish stocking, began in Yellowstone almost immediately upon the Park's establishment. David Starr Jordan's 1889 "Reconnaissance of the Streams and Lakes of Yellowstone National Park" (Figure 3) documented the extent of fish distributions in the major lakes and rivers of the Park, including the vast fishless area in the west of the park, before stocking efforts began. Since that time, park managers have been collecting and compiling data concerning all aspects of the park's aquatic resources. This data has led to the completion of many internal documents, technical reports, peer reviewed publications, articles, and books. The most complete compilation of these documents and publications exists in the Yellowstone Center for Resources library. This library was used to collect as much historical data as possible on all streams included in our Northern Range investigation. Information concerning physical characteristics of the streams was also collected from the Park's GIS database.

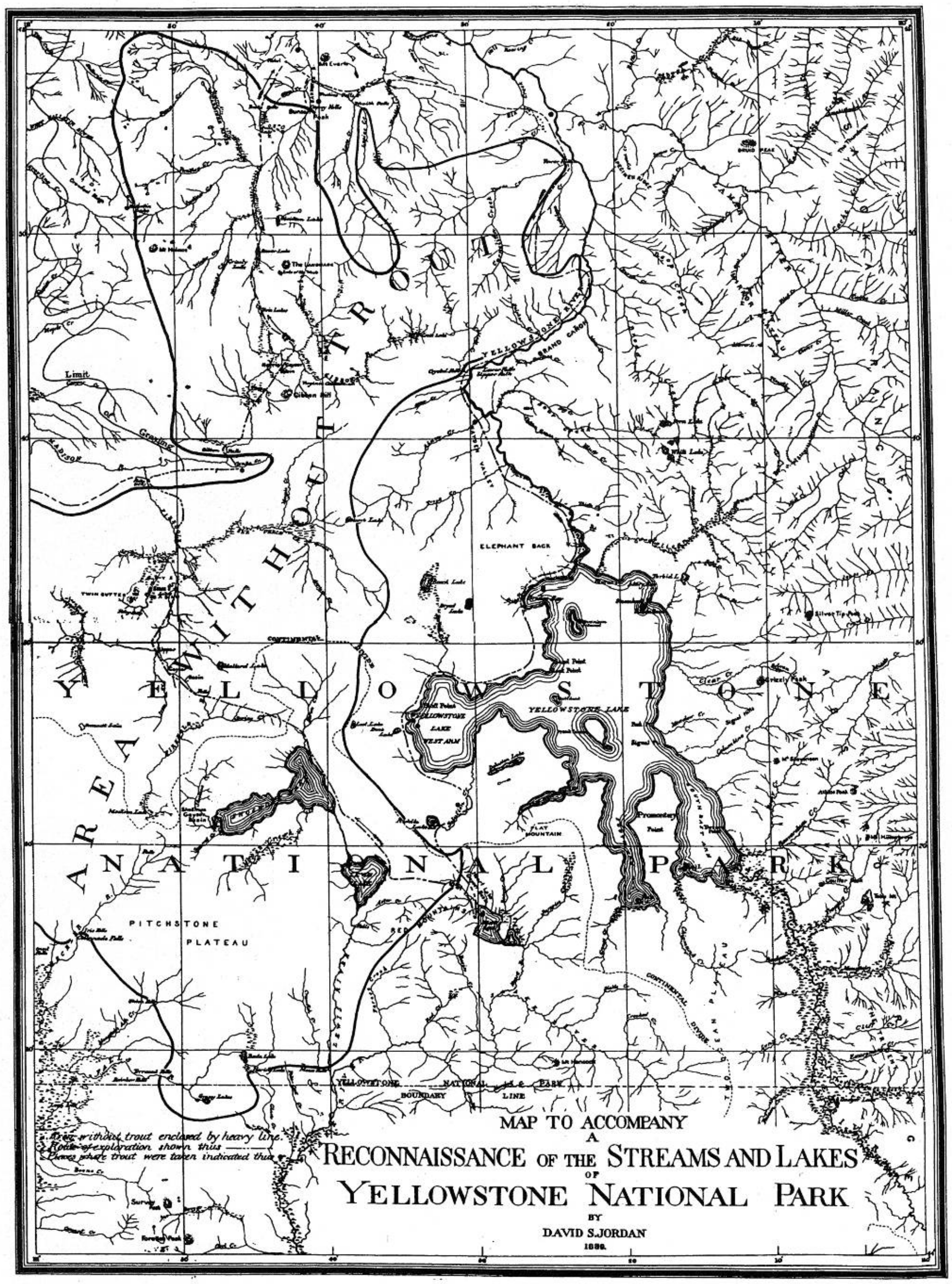

Figure 3. Map of original fish distribution, including vast fishless areas (Area Without Trout), in Yellowstone National Park produced by David Starr Jordan in 1889. (From Baron W. Everman, Report on the Establishment of Fish Culture Stations in the Rocky Mountain Region and Gulf States, U.S. Government Printing Office, 1892).

A wide range of parameters were established on topics including species composition and distribution, logistical aspects, and physicochemical properties (Table 1). All were deemed to be important to the potential success of native species restoration. The parameters were designed to address YCT restoration from a holistic perspective, including physical, biological, and anthropogenic aspects. Individual pieces of data were then gleaned from historical records for each stream and entered into a matrix. Some characteristics, such as degree of road accessibility, were assigned scores and entered as ordinal data. A preliminary review was completed early in the summer of 2005.

Field Investigations

The initial literature review was useful in identifying data gaps and subsequently establishing a sampling plan for the 2005 through 2007 field seasons. In order to maximize efficiency during these field seasons, initial sampling priority was given to streams with a high degree of accessibility. Streams that were known, or believed, to possess populations of cutthroat trout of unknown genetic status were also given sampling priority.

Identification of barriers to upstream fish movement was an important aspect of field investigations. A slope layer created from the Park's GIS elevation data was used to identify areas likely to contain natural fish barriers. Other features such as road culverts and irrigation diversions were also investigated as potential barriers (Image 1 A&B). In some cases, a barrier was known to exist in a particular watershed but the knowledge of fish species composition above and/or below the barrier was uncertain (Image 2A). In most cases, the barrier was a large prominent feature that presented a definitive impediment to upstream fish movement. In these situations, sampling was conducted by first locating the barrier and then sampling both up and downstream of it. If fish were captured below, but not above the barrier, the barrier location was deemed the upstream

Image 1. A) Road Culvert at the intersection of Elk Creek and Grand Loop Road. Sampling demonstrated that brook trout are present below but not above the culvert, indicating that the culvert is a barrier to upstream fish movement. B) Road Culvert at the intersection of Geode Creek and Grand Loop Road. Sampling demonstrated that cutthroat trout are present both above and below the culvert. However, the culvert is suspected of being a barrier to upstream fish movement.

Table 1. Classes of information collected for Northern Range streams during the literature review and recent field surveys (2005-2007).

Identification	**Biological**	**Physical**	**Chemical**	**Logistical**	**Anthropogenic**
Stream Name	Historic Species	Main Stem Length	pH	Existing Barrier	Interpretative Value
River Drainage	Current Species	Main Stem and Tributary Length	Mean August Temperature	Potential for Barrier Construction	Human Water Supply
SONYEW* #	Species Stocked	Mean Gradient		Road Access	Angler Use
	YCT Genetic Integrity	# of Tributaries		Trail Access	Jurisdiction
		Wetlands		Bear Management Area	
				Presence of Wetlands/Spring Seeps	

*System of Naming Yellowstone Waters

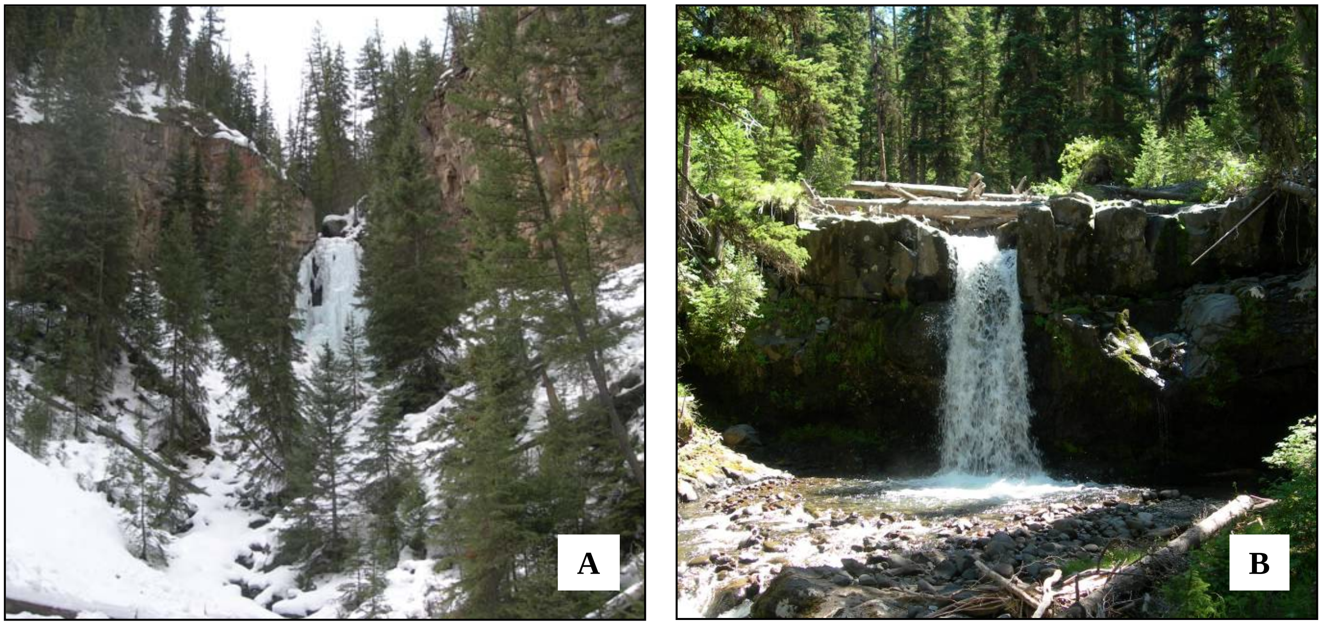

Image 2. A) Lost Creek Falls on Lost Creek. Example of a large prominent barrier to upstream fish movement with unknown fish distribution above and below it. B) Unnamed Waterfall on Amphitheater Creek. Example of a barrier not found in the GIS database that was encountered during sampling. Sampling demonstrated that fish are present below but not above the waterfall.

extent of fish distribution. If fish were captured above the barrier, sampling continued upstream until another barrier was located (Image 2B) or a 200 m reach of stream was sampled without capturing or observing any fish. A similar method was used in streams without previously identified barriers. In those streams, a fish sample was collected from an easily accessible point to document presence and species composition and potential barriers were then sought out. As mentioned above, sampling was halted when a definitive barrier was located or a 200 m reach of fishless stream was sampled. In this manner, upstream extent of fish distribution was estimated.

A minimum of 30 genetic samples, in the form of fin clips, were collected from every population of fish resembling cutthroat trout (Image 3 A&B), unless sufficient numbers of fish were unavailable. Additional samples were collected from streams with populations existing above and below known or suspected barriers. All fin clips were initially preserved in 70% isopropyl alcohol and were later transferred to 100% non-denatured alcohol. Genetic samples have been or will be analyzed for YCT, westslope cutthroat trout *(O. clarki lewisi, WCT)*, and RBT alleles and the results are being used to identify the genetic integrity of each population sampled. In some streams, electrophoretic genetic analyses were performed prior to this effort (Table 2). However, additional samples were collected in 2005 through 2007 in some of those locations to document any changes that may have occurred since the original collections were made.

Table 2. Results of electrophoretic genetic analysis performed at sites in Yellowstone's Northern Range. Results are reported as percentage of alleles in a given cutthroat trout population attributed to Yellowstone cutthroat trout (YCT), westslope cutthroat trout (WCT), and rainbow trout (RBT). Redundant samples were collected from upper Pebble Creek and Reese Creek in 2005.

Stream	Drainage*	General Location	# of Samples	Year Collected	Hybridization Detected	% YCT	%WCT	%RBT
Amphitheater Creek	LMR	Below Waterfall	8	2005	YES	96	0	4
Crystal Creek	LMR	Confluence w/Lamar R.	7	2005	YES	76	0	24
Lamar River	LMR	Lower	25	1993	YES	99	0	1
Lamar River	LMR	at Cache Creek	25	1993	NO	100	0	0
Lamar River	LMR	at Flint Creek	25	1993	NO	100	0	0
Lamar River	LMR	at Calfee Creek	25	1993	NO	100	0	0
Lamar River	LMR	Slough Cr. Confluence	37	2002	YES	64	1	35
Lamar River	LMR	Lamar River Canyon	10	2002	YES	90	0	10
Lamar River	LMR	Confluence w/Soda Butte Cr.	8	2002	YES	97	0	3
Lamar River	LMR	Above confluence w/Soda Butte Cr.	7	2002	NO	100	0	0
Lamar River	LMR		10	2002	NO	100	0	0
Lamar River	LMR	Geyser Basin	30	2003	YES	98	0	2
Mist Creek	LMR		26	1992	NO	100	0	0
Pebble Creek	LMR	Upper	25	1993	NO	100	0	0
Pebble Creek	LMR	Above first cascade	30	2005	NO	100	0	0
Rose Creek	LMR	Above Grand Loop Rd.	53	2005	YES	51	1	48
Slough Creek	LMR	Above Cascades	25	1994	NO	100	0	0
Slough Creek	LMR	Elk Tongue Cabin	46	2002	NO	100	0	0
Slough Creek	LMR	Lower Slough Cabin	60	2002	YES	88	1	11
Soda Butte Creek	LMR	Silver Gate	25	1992	YES	98	2	0
Soda Butte Creek	LMR	Above Icebox Canyon	39	2006	YES	98	1	1
Soda Butte Creek	LMR	Above Icebox Canyon	1	2006	YES	50	0	50
Stephens Creek	YSR	Above Stephens Creek Rd.	13	2006	YES	31	0	69
Antelope Creek	YSR	Below Waterfall; Above Canyon	40	2006	NO	100	0	0
Electric Creek	YSR	Confluence w/Reese Cr.	9	2005	NO	100	0	0
Geode Creek	YSR	Below Grand Loop Rd.	40	2005	NO	0	100	0
Reese Creek	YSR	Above Diversions	22	1990	YES	96	0	4
Reese Creek	YSR	Above 3rd Diversion	46	2005	YES	97	0	3

*LMR=Lamar River, YSR=Yellowstone River.

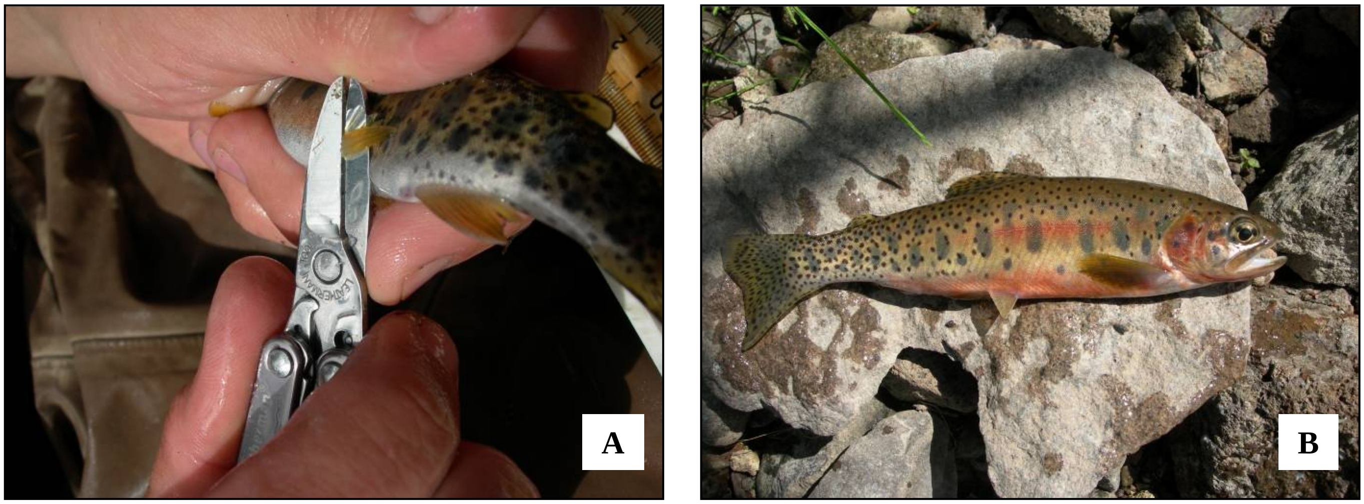

Image 3. A) Taking genetic samples, in the form of fin clips from a population of cutthroat trout in the Oxbow/Geode Creek complex. B) Example of a fish from which a genetic sample (right pelvic fin) has been collected.

Prioritizing Streams

Data collected through literature review, GIS analysis, and field investigations were used to develop a prioritization matrix. The matrix was created by selecting a set of 12 parameters and converting all fields to ordinal data (Table 3). Because parameters varied in the number of classes, all parameters were eventually standardized to a 10 point scale. In this way, all parameters were given equal weight in the prioritization matrix. A final score was calculated by adding each parameter score together for a total score. The streams with the highest scores were considered as having the greatest potential for successful YCT restoration. Ordinal scores, before standardization, were assigned as follows:

Parameter 1 - Historic vs. Current Species

0 = Historically and Currently Fishless or Currently YCT
1 = Historical or Current Status Unknown
2 = Historically Fishless and Currently Nonnative or Hybrid
3 = Historically YCT and Currently Nonnative or Hybrid

Historically fishless waters are important natural ecosystems and are therefore highly valued by the National Park Service. As such, waters that have retained fishless status were not considered for YCT restoration projects. In the same respect, waters that maintained their status as genetically pure YCT, or historically fishless waters where pure YCT now exist, were not considered for restoration projects. A score of zero in this category removed the listed water from further consideration.

In many of the small headwater streams on the northern range, the historic and/or current species composition is unknown. Future sampling seeks to answer questions about current species distribution, but, in many cases, historic species status was

Table 3. Parameters and ordinal scores (before standardization to 10 point system) used to build the streams prioritization matrix.

SCORE	**Historic vs Current Species**	**YCT Genetic Integrity**	**Potential for Barrier Construction**	**Road Access**	**Trail Access**	**Interp. Value[1]**	**BMA[2]**	**Main Stem Length**	**# Tribs**	**Wetlands**	**Human Water Supply**	**Jurisdiction**
0	Historically Fishless/YCT and Currently Fishless/YCT	Entire Reach Pure YCT	Low	None	None	Low	Majority Closed Entire Season	<5 km or >25 km	>20	Many	Yes	Stream Extends Beyond Park Boundary
1	Unknown	Unknown	Moderate	Limited	Limited	Moderate	Majority Closed Part of Season	5 - 7.5 km or 22.5-25 km	11-20	Some	No	Stream Entirely Within Park Boundary
2	Historically Fishless; Currently Nonnative	Hybridized YCT	High	Abundant	Abundant	High	Portion Closed Entire Season	7.5-10 km or 20-22.5 km	0-10	Few		
3	Historically Pure YCT; Currently Nonnative	Nonnative	Existing Barrier				Portion Closed Part of Season	10-12.5 km or 17.5-20 km		Very Few		
4		Portion of Reach Pure YCT					Little or No Conflicts	12.5-17.5 km				

[1]Interpretative Value, [2]Bear Management Area

undeterminable because of incomplete records. This situation was addressed by assigning the stream in question a score of one. Streams that were historically fishless but had been invaded by nonnatives were assigned a score of two. These streams were considered as restoration candidates because recreational fisheries important to park visitors have already been established in many of these areas. Further, it is likely that the unique fauna usually present in fishless waters (amphibians, invertebrates, etc.) has already been impacted.

We consider streams that were known to historically contain pure YCT which have now been replaced with or hybridized by nonnatives as ideal candidates for restoration. In these streams, YCT were part of the historic ecosystem and the reestablishment of pure strain populations would meet the technical definition of watershed level restoration. Stream that fall into this category were assigned a score of three.

<u>Parameter 2 - Yellowstone Cutthroat Trout Genetic Integrity</u>

0 = Entire stream genetically pure YCT or fishless
1 = Presence of fish or genetic status unknown
2 = Entire stream hybridized
3 = Entire stream nonnative
4 = Portion of stream genetically pure

Streams that contain genetically pure YCT were not considered for restoration and were assigned a score of zero. In many streams, the genetic integrity of the cutthroat trout that are present is unknown because either electrophoretic genetic analyses have not yet been performed or sampling has never occurred in the waters. A score of one was given to these streams. A stream where the population is known to be hybridized to any extent was assigned a score of two. Streams where populations of YCT have been largely replaced by nonnative species, like BKT, were given high priority and assigned a score of three. Highest priority was given to streams containing pure strain populations of YCT that exist above a portion of stream that is either hybridized or occupied by nonnatives. Restoration of these streams would allow gene flow from the existing population into the renovated stream reach. A score of four was given to these streams.

<u>Parameter 3 - Barriers</u>

0 = Stream morphology not conducive to barrier construction
1 = Stream morphology conducive to barrier construction
2 = Existing structure can be modified to create barrier
3 = Existing barrier

The ability to build effective barriers is important in conducting fish restoration projects. Streams that were not morphologically conducive to barrier construction, because they had low gradient and/or volatile channels scored the lowest. Streams that have morphological characteristics that are favorable to building barriers were assigned a score of one. Stream with structures such as irrigation diversions or road culverts that could be modified to exclude upstream fish movement were assigned a score of two. The most favorable situation for restoration is existence of a natural barrier. Streams with existing barriers were given a score of three.

<u>Parameter 4 - Road Access</u>

0 = None
1 = Limited
2 = Abundant

The degree of road accessibility is an important factor affecting large scale fish restoration projects. Many streams in Yellowstone are completely within backcountry areas and are not accessible by road. Streams with no road access were assigned a score of zero. Streams that are intersected at only one point were given a score of one. Some streams are crossed by roads at multiple locations or are paralleled by roads and were therefore assigned a score of two.

<u>Parameter 5 - Trail Access</u>

0 = None
1 = Limited
2 = Abundant

Much like road access, trail access is important to restoration projects from a logistical perspective. Streams that are not accessible by trail were given a score of zero. Streams that are only crossed by trails at one or two points are considered to have limited accessibility and were assigned a score of one. Streams that are crossed many times or paralleled by trails were given a score of two.

<u>Parameter 6 - Interpretative Value</u>

0 = Low Traffic
1 = Moderate Traffic
2 = High Traffic

Educating the public is an important aspect of many projects within the park and native fish restoration is no exception. Interpretative sites are useful in helping the public understand the scope of and need for cutthroat trout restoration projects, and the success of an interpretative site is strongly influenced by the number of people who visit it. Therefore, streams that exist entirely within the backcountry, and thereby receive low levels of pedestrian traffic, were assigned a score of zero. Streams crossed by minor roads, moderate traffic sites, were assigned a score of one. Higher traffic areas with pull-offs on major roads are the most ideal locations for interpretative sites. High traffic sites were given a score of two.

<u>Parameter 7 - Bear Closure Areas</u>

0 = Majority of watershed in area closed during entire field season
1 = Majority of watershed in area closed during part of the field season
2 = Portion of watershed in area closed during entire field season
3 = Portion of watershed in area closed during part of the field season

4 = No conflict with bear closure areas

In Yellowstone National Park, the management of grizzly bears includes restriction of human access to certain regions of the park at various times of the year (NPS 1983). These closure areas exclude the public from entry into designated areas and restrict access to the areas by park personnel. While access to closed areas can be arranged by special permission, a project of the scope and scale of native fish restoration would be a significant disturbance. For this reason, conducting projects in bear closure areas would not be optimal. Bear closure areas vary in dates and duration of closure; some areas are permanently closed while others are closed only temporarily. Bear closures affect restoration efforts if the closures are concurrent with the normal fisheries field season (June, July, August, and September).

Streams that occur largely within areas that are closed during the entire field season were given a score of zero. If the majority of the stream lies within an area that is closed during part of the field season, a score of one was given. A score of two was assigned to streams that only partially exist within an area that is closed for the entire field season. Streams that occur in areas closed during some of the field season were given a score of three. Streams with no conflicts with bear closure areas were assigned a score of four.

Parameter 8 - Stream Main Stem Length

0 = <5 km or >25 km
1 = 5.0 - 7.5 km or 22.5 - 25.0 km
2 = 7.5 - 10.0 km or 20.0 - 22.5 km
3 = 10.0 - 12.5 km or 17.5 - 20.0 km
4 = 12.5 - 17.5 km

Stream size is an important consideration when undertaking fish restoration projects for several reasons. Small streams may not be able to support self sustaining fish populations without immigration from other sources, making it impractical to isolate them with a barrier. Small populations also suffer from higher extinction risk due to stochastic events than do larger populations (Shepard et al. 2005). The potential cost benefit ratio, in length of stream restored or number of fish reestablished, is also higher in small streams than in larger waters. However, smaller projects are often more logistically simple and may have a higher chance of ultimate success than larger projects. Therefore, streams that are neither too large nor too small are most desirable. For this reason, our scoring system for stream size essentially follows a normal curve.

We chose to use main stem stream length as our measure of stream size. This enabled us to gather accurate data for any stream using the Park's GIS database, and gave us a measure of the logistical complexity of potential projects from a perspective not provided by flow, watershed area, or stream order. Ideal length range was selected using streams of known size that were previously considered an ideal size for native fish restoration projects. Streams considered to be too small, less than 5 km, or too large, greater than 25 km, were assigned a score of zero. Small, between 5.0 and 7.5 km, and large, between 22.5 and 25.0 km, were given a score of one. Streams between 7.5 and 10.0 km or 20.0 and 22.5 km were assigned a score of two. Streams between 10.0 and

12.5 km or 17.5 and 20.0 km were given a score of three. Ideal stream size was considered to be between 12.5 and 17.5 km, therefore streams of that length were assigned a score of four.

Parameter 9 - Number of Tributaries

0 = >20
1 = 11-20
2 = 0-10

Tributaries complicate restoration efforts by adding waters to the main stem that may or may not need to be treated to eradicate nonnative fish. Because little information exists concerning the hundreds of unnamed tributaries in the Northern Range, and collecting data on even a fraction of them would be a monumental task, we used the raw number of unnamed tributaries as a parameter in our analysis. We considered a low number of tributaries to be an ideal situation. Therefore, streams with more than 20 tributaries were assigned a score of zero. Streams with a moderate number of tributaries, between 11 and 20, were given a score of one. Because a low number of tributaries was considered an ideal situation streams with 0 to 10 tributaries were assigned a score of two.

Parameter 10 - Wetlands

0 = Many
1 = Some
2 = Few
3 = Very Few

Wetlands, much like tributaries, can add logistical difficulty to a fish restoration project by adding extra size to the area that requires treatment. In addition, because water movement through wetlands is often slow and convoluted, and dense vegetation inhibits the application of piscicides, wetlands can be very difficult to effectively treat. Therefore, the higher the percentage of the stream that is bordered by wetlands the more difficult it will be to successfully eradicate fish from the stream.

Streams that had a high propensity of low gradient reaches, and therefore many surrounding wetlands, were given a score of zero. Streams where bordering wetlands were common but not abundant were assigned a score of one. Streams where surrounding wetlands were uncommon were given a score of two. The ideal situation was for a stream to be connected to very few or no wetland areas, these streams were assigned a score of three.

Parameter 11 - Human Water Supply

0 = Yes
1 = No

Some surface waters in the park are used as drinking water supplies for developed areas. Treating these waters with fish toxins would present a logistical problem, as water intakes would have to be shutoff during chemical treatments. Public perception about applying a fish toxin to a drinking water supply may also impede completion of proposed projects.

For these reasons, we considered the water supply issue in our analysis. Because only two conditions occur, that is a stream either is or is not a public water supply, streams that are used for drinking water were given a score of zero and streams that were not were given a score of one.

Parameter 12 - Jurisdiction

0 = Stream extends beyond park boundary onto other lands
1 = Stream exists entirely within the Yellowstone National Park boundary

Most streams under consideration lie entirely within the boundaries and, therefore, the jurisdiction of Yellowstone. A few streams cross park boundaries flowing either into or out of the park. From a logistical standpoint, projects are simpler when only one agency has administrative jurisdiction. It is important to understand that inclusion of this parameter does not represent an unwillingness of the NPS to work with other agencies; it only recognizes the trend of increased logistical complexity as the number of agencies and private stakeholders involved increases. In using the jurisdiction criteria we only considered two conditions. Either the stream crossed into or out of the park and was therefore assigned a score of zero, or it occurred entirely within park boundaries and was assigned a score of one.

RESULTS

In Yellowstone's Northern Range, few waters have escaped invasion by nonnative fish species. Included in these waters are the upper Lamar River, upper Pebble Creek, and numerous small fishless streams. In most cases, the waters are isolated by a physical barrier and any stockings that were attempted above the barriers were unsuccessful (Image 4) or as may have happened in the case of Antelope Creek, the stream was stocked with native cutthroats and the fish have persisted in their genetically pure form.

Antelope Creek parallels Grand Loop Road in the Tower area as it flows south towards its confluence with the YSR (Figure 4). Historical Records indicate that the stream was fishless above a 3.0 m unnamed waterfall 1.3 km upstream of the confluence (Image 5A). Data concerning the exact location and size of the waterfall were lacking before a 2006 survey located it and identified it as a complete barrier to upstream fish movement. A review of stocking records indicates that Antelope Creek was never part of official recorded park stocking efforts, but recent sampling has revealed that the stream is home to a population of cutthroat trout (Image 5B).

Image 4. Fairies Falls on Amethyst Creek. Example of a well known, prominent barrier to upstream fish movement. Stocking did occur on Amethyst Creek, presumably above the barrier, but 2005 sampling revealed that fish have not persisted in the stream.

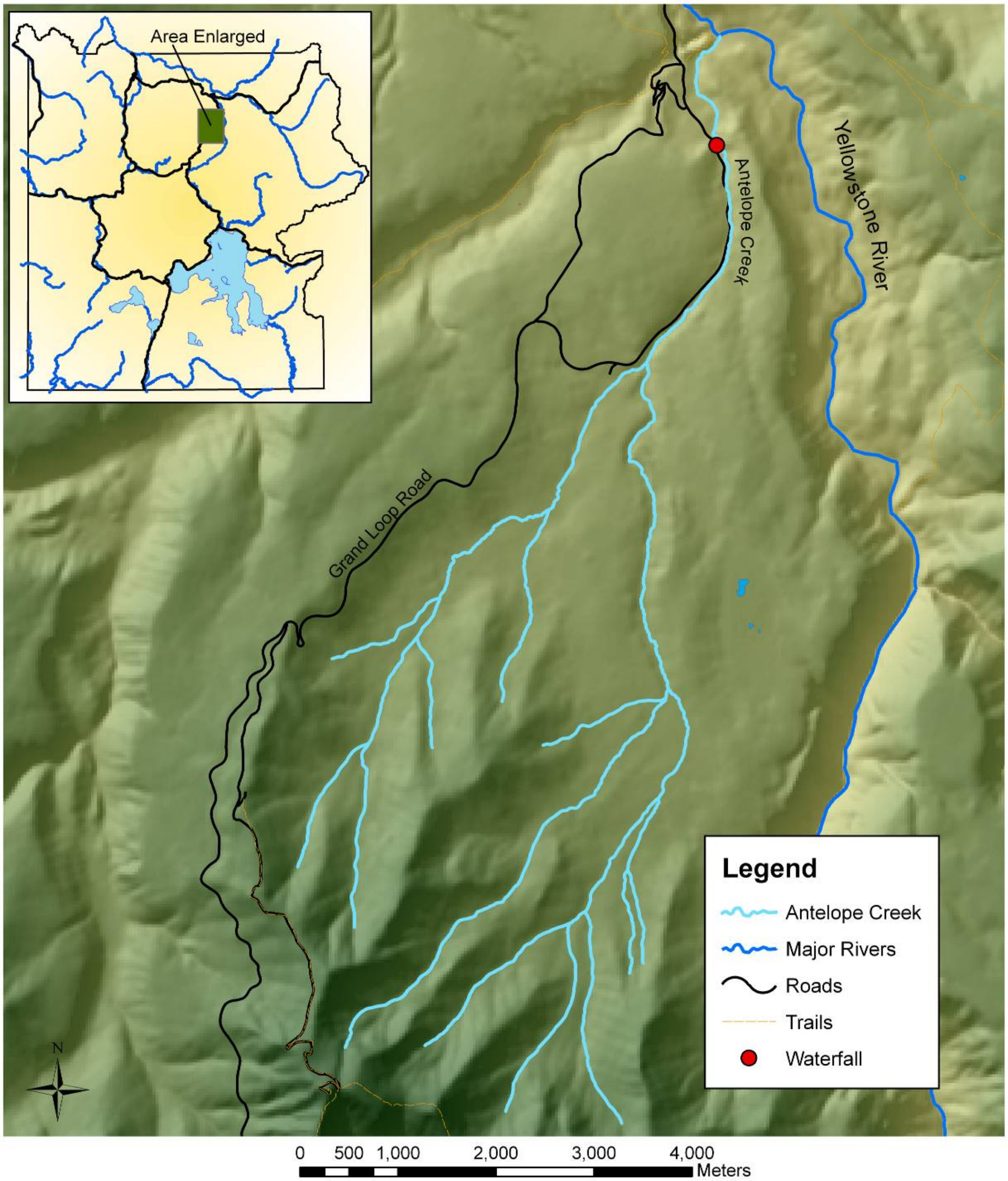

Figure 4. The Antelope Creek watershed with location of unnamed waterfall (Image 5A) that protects the genetic purity of the Yellowstone cutthroat trout in the stream's upper reaches.

Image 5. A) Unnamed Waterfall on Antelope Creek. B) Example of a genetically pure YCT from Antelope Creek.

As no stocking records are available, this population is of unknown origin but genetic analysis completed during the winter of 2006 revealed that the population is genetically pure YCT. Varley and Schullery (1998) indicated that brook trout may also be present in the system and annual angler survey information supports the claim. However, sampling by fisheries staff from 2000 to present has failed to capture any species other than cutthroat trout. Genetic analysis also revealed that another barrier to upstream fish movement may be present in the very steep 250 m canyon reach of Antelope Creek that occurs immediately before its confluence with the YSR. As with the reach upstream of the waterfall, only genetically pure YCT were found between the canyon and the waterfall.

The confirmation of genetically pure YCT in Antelope Creek is exciting because it marks the stream as one of only a handful of small headwater drainages in Yellowstone's Northern Range that contain pure YCT. It is likely that fish from Antelope Creek will eventually play an important role in the recovery of YCT elsewhere in the region.

Most waters not possessing a barrier that were not directly stocked appear to have been subsequently invaded by nonnative species from downstream reaches. Because of this, the current distribution of native fishes is vastly different from that which existed when the park was first established in 1872.

Our initial literature review identified gaps in our understanding of many of the remote backcountry streams in the Northern Range. Surprisingly, however, even some of the easily-accessible, front-country streams were not often or never sampled in the past by park fisheries biologists. As a result, a total of 15 front-country streams were surveyed for fishes and habitat attributes during the field seasons of 2005 – 2007. Daily activity reports, including maps, important GPS coordinates, and copies of original data forms were placed on file at the Yellowstone Center for Resources. Data from field investigations were also integrated into our existing Northern Range streams database.

A data matrix (Table 4) was used to score and rank the 56 Northern Range streams originally under consideration for restoration. Twenty four streams were immediately removed from the analysis because they met one of our requirements for exclusion (because of main stem length and/or historic vs. current species status). The 32 streams that remained were included in our analysis and the top 10 are described in some detail here (Figure 5; Table 5).

Table 4. Northern Range streams prioritization matrix with all exclusions removed.

RANK	Stream	Drainage	Spec.[1]	Gen Intg[2]	Barr[3]	Rd Acc.[4]	Tr Acc.[5]	Interp[6]	Bears[7]	Length[8]	# Tribs[9]	Wetlands[10]	WS[11]	JD[12]	TOTAL SCORE
1	Elk Creek	YSR	6.7	7.5	10.0	10.0	10.0	10.0	7.5	10.0	10.0	6.7	10	10	108.33
2	Yancey Creek	YSR	6.7	7.5	6.7	10.0	10.0	10.0	10.0	0.0	10.0	10.0	10	10	100.83
3	Lost Creek	YSR	6.7	7.5	6.7	10.0	10.0	10.0	7.5	10.0	10.0	0.0	10	10	98.33
4	Rose Creek	LMR	10.0	5.0	6.7	10.0	0.0	10.0	10.0	5.0	10.0	10.0	10	10	96.67
5	Glen Creek	GDR	6.7	7.5	10.0	5.0	10.0	10.0	5.0	5.0	10.0	0.0	0	10	79.17
6	Blacktail Deer Creek	YSR	10.0	7.5	10.0	5.0	5.0	10.0	5.0	2.5	0.0	3.3	10	10	78.33
7	Geode Creek	YSR	3.3	7.5	6.7	5.0	5.0	5.0	10.0	2.5	10.0	3.3	10	10	78.33
8	Stephens Creek	YSR	3.3	5.0	6.7	5.0	0.0	5.0	10.0	2.5	10.0	10.0	10	10	77.50
9	Oxbow Creek	YSR	3.3	7.5		5.0	0.0	10.0	7.5	10.0	10.0	3.3	10	10	76.67
10	Reese Creek	YSR	10.0	5.0	6.7	5.0	0.0	5.0	5.0	7.5	10.0	10.0	10	0	74.17
11	Land Slide Creek	YSR	3.3	2.5	6.7	5.0	0.0	5.0	10.0	2.5	10.0	6.7	10	10	71.67
12	Moss Creek	YSR	3.3	2.5	10.0	0.0	5.0	0.0	10.0	7.5	10.0	3.3	10	10	71.67
13	Cutoff Creek	LMR	3.3	0.0	10.0	0.0	5.0	0.0	10.0	2.5	10.0	10.0	10	10	70.83
14	Panther Creek	GDR	6.7	7.5	6.7	5.0	10.0	5.0	0.0	7.5	10.0	0.0	0	10	68.33
15	Chalcedony Creek	LMR	3.3	2.5	10.0	0.0	0.0	0.0	10.0	5.0	10.0	6.7	10	10	67.50
16	Fawn Creek	GDR	6.7	7.5		0.0	10.0	0.0	0.0	10.0	10.0	0.0	10	10	64.17
17	Burnt Creek	YSR	3.3	2.5	10.0	0.0	0.0	0.0	5.0	10.0	10.0	3.3	10	10	64.17
18	Carnelian Creek	YSR	6.7	7.5		0.0	0.0	0.0	7.5	7.5	10.0	3.3	10	10	62.50
19	Rescue Creek	YSR	3.3	2.5		0.0	10.0	0.0	10.0	2.5	10.0	3.3	10	10	61.67
20	Hornaday Creek	LMR	3.3	2.5		0.0	5.0	0.0	10.0	5.0	5.0	10.0	10	10	60.83
21	Indian Creek	GDR	6.7	7.5	3.3	0.0	5.0	0.0	0.0	10.0	10.0	6.7	0	10	59.17
22	Ltl. Buffalo Creek	YSR	3.3	2.5		0.0	5.0	0.0	10.0	5.0	10.0	3.3	10	10	59.17
23	Coyote Creek	YSR	3.3	2.5	10.0	0.0	5.0	0.0	10.0	7.5	10.0	0.0	10	0	58.33
24	Crevice Creek	YSR	3.3	2.5		0.0	5.0	0.0	10.0	7.5	10.0	10.0	10	0	58.33
25	Cottonwood Creek	YSR	3.3	2.5		0.0	5.0	0.0	10.0	5.0	10.0	10.0	10	0	55.83
26	Ltl. Cottonwood Creek	YSR	3.3	2.5		0.0	5.0	0.0	0.0	2.5	10.0	10.0	10	10	53.33
27	Jasper Creek	LMR	3.3	2.5		0.0	0.0	0.0	10.0	2.5	10.0	3.3	10	10	51.67
28	Little Blacktail Deer Cr.	YSR	3.3	7.5		0.0	0.0	0.0	2.5	7.5	10.0	0.0	10	10	50.83
29	Willow Creek	LMR	3.3	2.5		0.0	0.0	0.0	0.0	5.0	10.0	3.3	10	10	44.17
30	Opal Creek	LMR	3.3	2.5		0.0	0.0	0.0	0.0	2.5	10.0	3.3	10	10	41.67
31	Twin Creek	LMR	3.3	2.5		0.0	0.0	0.0	0.0	2.5	10.0	3.3	10	10	41.67

[1]Historic vs. Current Species;[2]Yellowstone Cutthroat Trout Genetic Integrity;[3]Barrier Status; [4]Road Access;[5]Trail Access;[6]Interperatative Value;[7]Access restrictions due to Bear Management;[8]Mainstem Length;[9]Number of Tributaries;[10]Presence of Wetlands and Spring Seeps;[11]Human Water Supply;[12]Jurisdiction.
GDR= Gardiner River, LMR= Lamar River, YSR= Yellowstone River

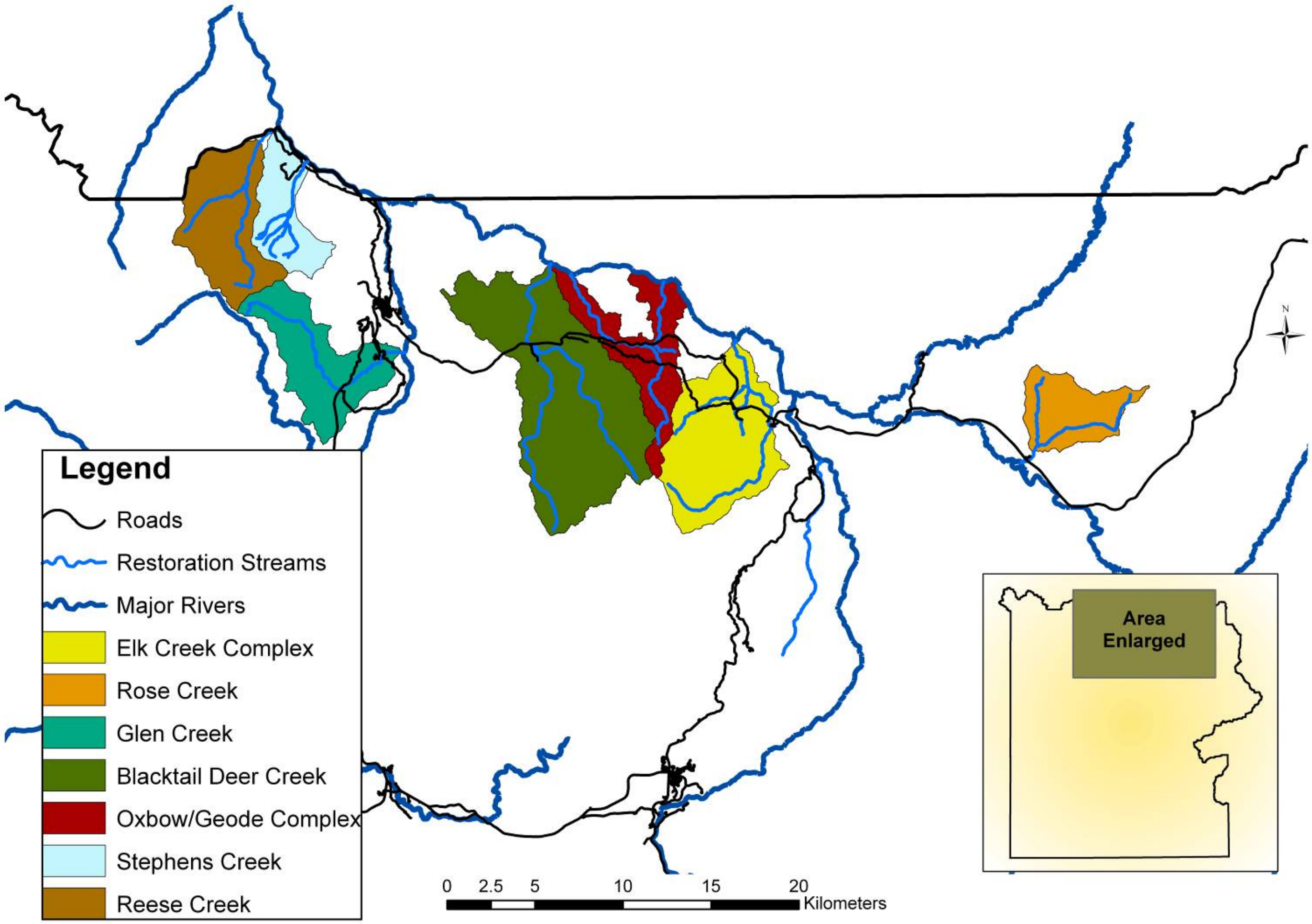

Figure 5. Watersheds that contain the top ten stream candidates for cutthroat trout restoration identified through the prioritization process.

Table 5. Top 10 restoration streams with details on parameters used in the prioritization process.

Rank	Stream	Drainage	Historic Species	Species Present	CTT Gen Integrity	Permanent Barrier	Road Access	Trail Access	Interpretive Value	Human Water Supply	Bear Closures	Mainstem Length	# of Tribs	Wetlands	Jurisdiction
1	Elk Cr.	YSR	FLS	BKT	N/A	Cascades	GLR	Good	Good	NO	Restricted 3/10 -7/31	16151 m	3	Few	YNP
2	Yancey Cr.	YSR	FLS	BKT	N/A	N/A*	GLR	Good	Good	NO	Restricted 3/10 -7/31	3221 m	2	Very Few	YNP
3	Lost Cr.	YSR	FLS	BKT	N/A	N/A*	GLR	Good	Good	NO	Restricted 3/10 -7/31	12984 m	5	Many	YNP
4	Rose Cr.	LMR	YCT	HYB	52%	None	NER and LSR	None	Good	NO	None	9193 m	6	Very Few	YNP
5	Glen Cr.	GDR	FLS	BKT	N/A	Glen Creek Falls	GLR	Good	Good	YES	Closed 5/25 -10/10	21943 m	2	Many	YNP
6	Blacktail Deer Cr.	YSR	YCT	BKT	N/A	Hidden Falls	GLR	Poor	Good	NO	Multiple Closures	20150 m	26	Some	YNP
7	Geode Cr.	YSR	FLS	WCT	100%	Cascades	GLR and BPD	Poor	Fair	NO	None	5430 m	1	Some	YNP
8	Stephens Cr.	YSR	YCT	HYB	31%	None	SCR and LSR	None	Fair	NO	None	6544 m	3	Very Few	YNP
9	Oxbow Cr.	YSR	FLS	WCT	100%	Unknown	GLR and BPD	None	Good	NO	Restricted 3/10 -7/31	14308 m	3	Some	YNP
10	Reese Cr.	YSR	YCT	HYB	97%	Irrigation Diversion	SCR and BPD	None	Fair	NO	Permanently Closed	11620 m	5	Very few	YNP, GNF, PRV

*Streams are part of a larger system with a barrier.
GLR= Grand Loop Road, LSR= Local Service Road, NER= Northeast Entrance Road
BKT= Brook Trout, FLS= Fishless, HYB= Cutthroat X Rainbow Trout Hybrids, WCT= Westslope Cutthroat Trout
SCR= Stevens Creek Road, BPD= Blacktail Plateau Drive
GDR= Gardner River, LMR= Lamar River, YSR= Yellowstone River
GNF= Gallatin National Forrest, PRV= Private Lands, YNP= Yellowstone National Park

Restoration Priorities 1, 2, & 3 - Elk, Yancey, and Lost Creeks

Elk, Yancey, and Lost creeks form a large, integrated system (Elk Creek complex) that is tributary to the Yellowstone River and located near the Tower Ranger Station (Figure 6). Yancey and Lost creek are tributaries to Elk Creek; the confluence of Lost Creek is 3.2 km upstream from the Yellowstone River, and Yancey Creek enters Lost Creek 200 m upstream from there. A barrier exists in the lower reach of Elk Creek in the form of a series of cascades approximately 700 m upstream from the Yellowstone River (Image 6). This barrier is not shown in the parks' GIS database but an exact location of the feature was recorded during a 2006 sampling event.

Image 6. Cascade barrier in the lower reaches of Elk Creek.

The Elk Creek complex was fishless until cutthroat trout were introduced in 1922-24 and brook trout were introduced in 1942 (Varley 1981). Recent sampling indicates that brook trout have out-competed cutthroat trout and are now the sole fish in the Elk Creek complex. Interestingly, however, a 1985 electro-fishing survey did capture one rainbow trout along with several brook trout in Elk Creek upstream of the lower cascades. The origin of this rainbow trout is unclear and, because no genetic sample was collected, the fish's exact genetic composition remains unknown. It is also possible that the 1985 record is a error.

Surveys conducted in 2005 demonstrated that brook trout remain abundant in upper Elk, Lost, and Yancey Creeks, and that no other fish species are present. Additional sampling in 2006 on lower Elk Creek captured only brook trout above the cascades, despite the presence of both brook and cutthroat trout below the cascades and downstream to the Yellowstone River. No evidence was found that would indicate that a population of rainbow or cutthroat trout exists in the system above the cascades, and it appears unlikely that these cascades are passable by fish moving upstream from the Yellowstone River. Further sampling and testing will be conducted to ensure that the cascades are an effective barrier and effectively preclude upstream fish movement.

Restoration Priority 4 – Rose Creek

Rose Creek is a Lamar River tributary that bifurcates in the area of the Lamar Ranger Station (Buffalo Ranch) in the northeastern region of the park (Figure 7). The stream is comprised of two primary tributaries, including the North Fork and the East Fork, whose confluence is approximately 900 m upstream from the Ranger Station. Rose Creek crosses the Northeast Entrance road approximately 400 m upstream of its confluence with the Lamar River. No barriers to upstream fish movement have been identified in the system. Genetic analysis has revealed that the fish present in Rose Creek

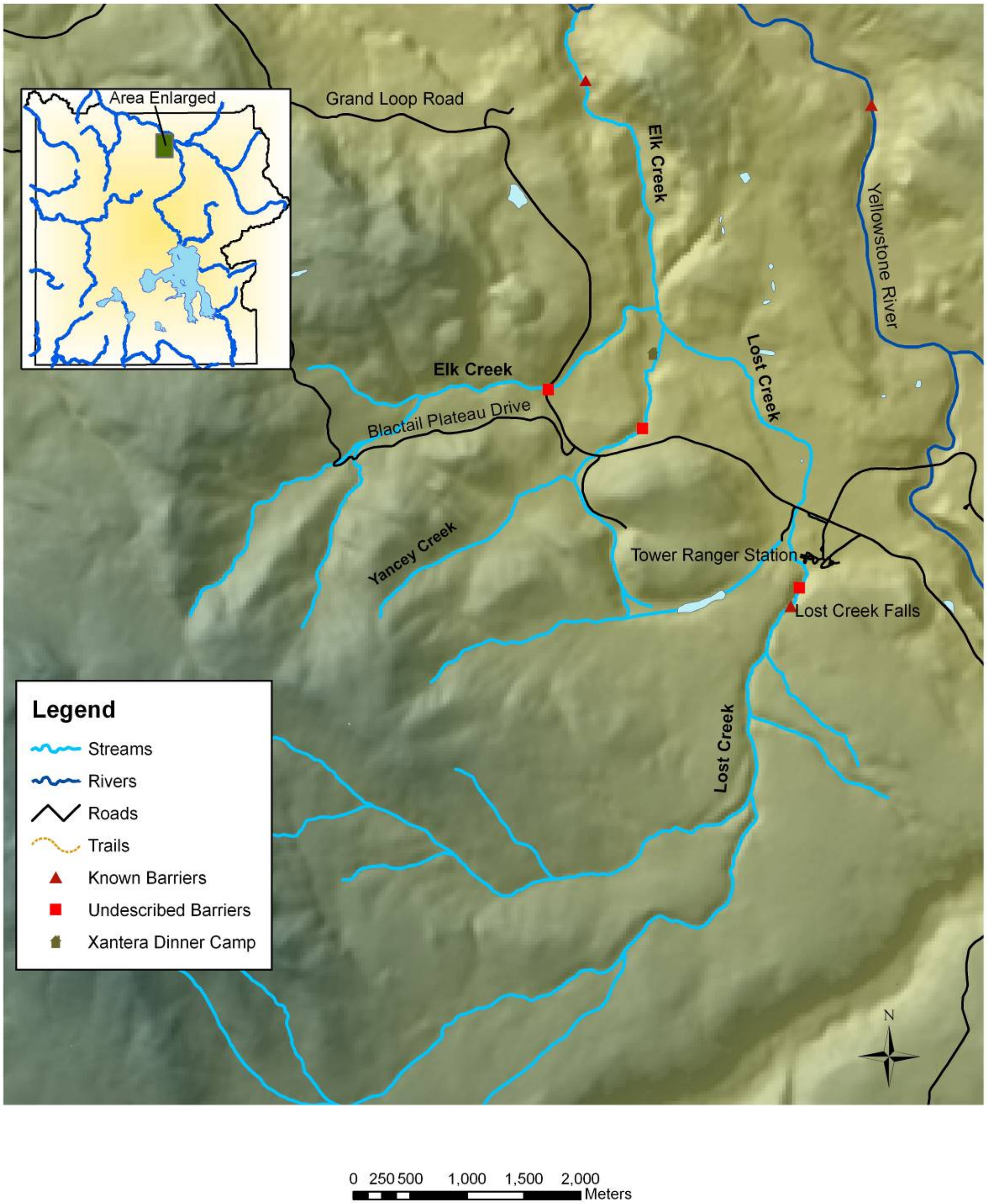

Figure 6. The Elk Creek complex including Elk, Lost, and Yancey Creeks with known (Images 2A and 6) and previously undescribed barriers (Image 1A) to upstream fish movement.

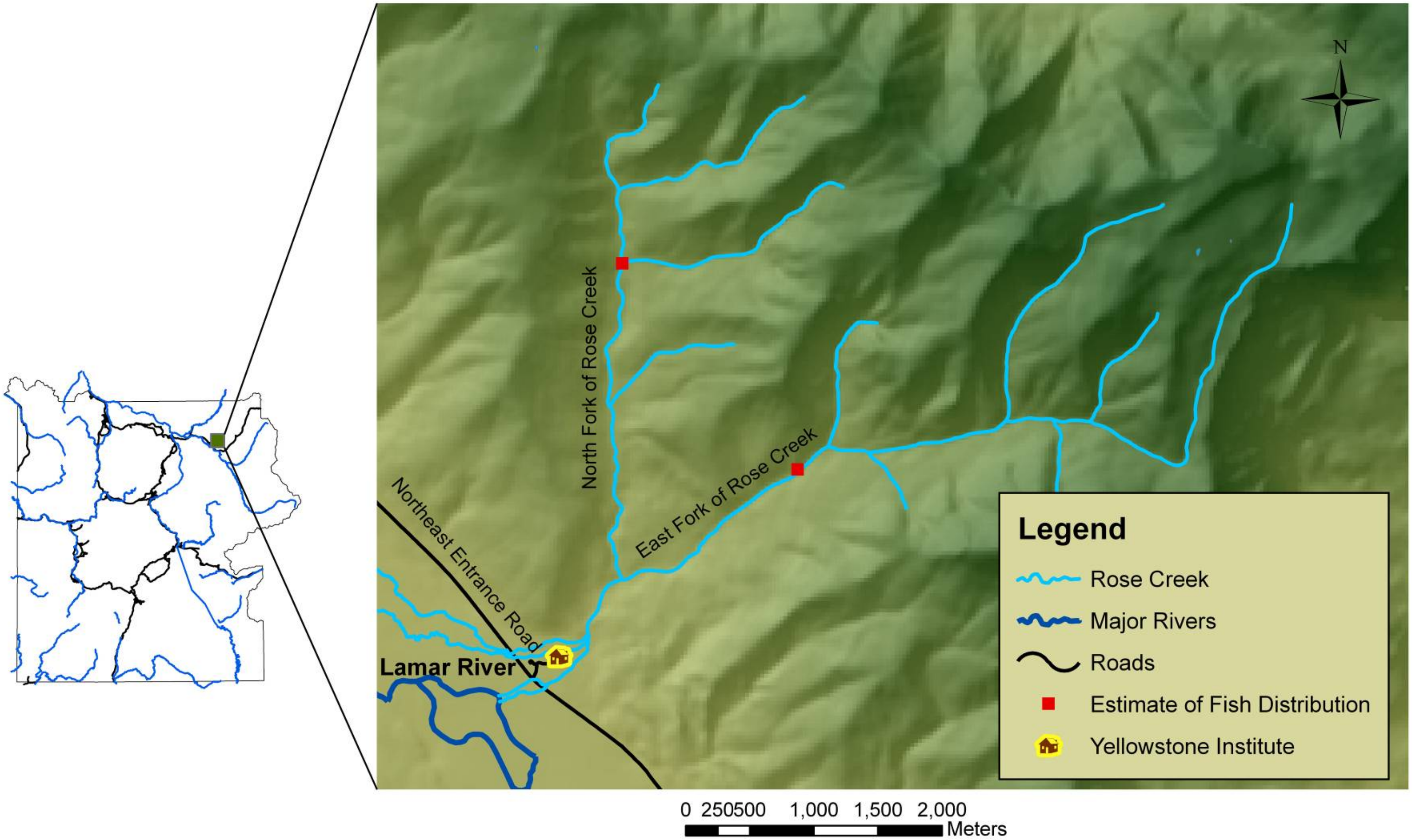

Figure 7. The Rose Creek watershed with estimated upstream extent of fish distribution and location of the Yellowstone Institute (Image 8).

Image 7. Examples of suspected rainbow x cutthroat trout hybrids from Rose Creek.

are cutthroat x rainbow hybrids (Image 7) and that hybridization between the cutthroat trout and the rainbow trout is on-going. Rose Creek appears to be a relatively productive system and fish are abundant in its lower reaches (Figure 8A). The main stem and lower reaches of the forks are low gradient, with the gradient increasing as the forks ascend their respective drainages.

Historic fish sampling conducted in the Rose Creek drainage was restricted to lower reaches of the system, so documentation of the uppermost extent of fish distribution in the system was completed in 2005. Trout were found in the North Fork within several hundred meters (downstream) of its confluence with a second unnamed tributary in the drainage. The North Fork and this unnamed tributary are of similar, small size at the point of confluence. Both were sampled for >200 m upstream and no fish were found in either of them. It appears likely that neither stream is large enough to support a population of trout.

The East Fork of Rose Creek is higher gradient than the North Fork and it appears that fish distribution may be limited by this factor. The portion of the East Fork that was sampled contained numerous log jams and boulder cascades that may not individually be definitive barriers, but cumulatively may be limiting the upstream extent of trout in the stream. Fish were captured in the East Fork up to the base of a large log jam approximately 1.5 km upstream from the its confluence with the North Fork. No tributaries containing fish were encountered.

The road culverts under the Northeast Entrance road through which Rose Creek passes on its way to the Lamar River may present an opportunity to create a functional fish barrier by modification of existing structures. Four culverts, three of them carrying

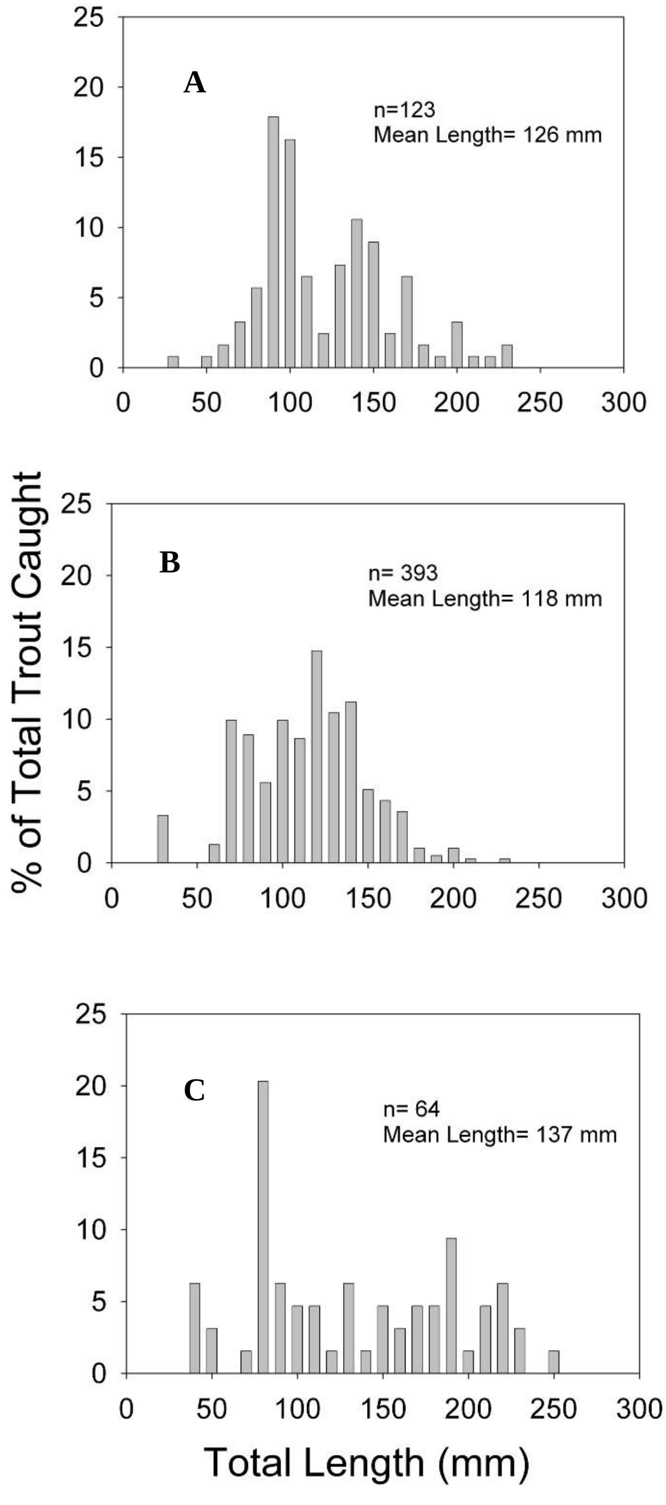

Figure 8. Length frequency histograms for A) cutthroat trout and rainbow/cutthroat trout hybrids (Image 7) from the main stem of Rose Creek in July 2005, B) westslope cutthroat trout (Image 10) from the Oxbow/Geode Creek Complex upstream of Blacktail Plateau Drive in August 2005, and C) rainbow/cutthroat trout hybrids (Image 13) from Reese Creek above the third irrigation diversion (Image 12) in June 2005.

flow, were identified and photographed in May of 2006. The four channels exist at the road because the stream has been modified and is now highly braided as it flows through the Lamar Ranger Station area. These unnatural, braided stream channels appear to be the result of human activity associated with the historic Buffalo Ranch that was once operated in this area. Modification of all four culverts at the road crossing would be required to create a functional barrier to upstream movement of rainbow trout from the Lamar River.

In total, approximately 5.7 km of stream were found to support trout in the Rose Creek drainage and there are few associated, off-channel wetland areas, making treatment by piscicides here much less complex. In addition, Rose Creek presents an excellent opportunity to provide public education on native fish restoration in Yellowstone. Several of the buildings at the historic Buffalo Ranch are used by the Yellowstone Association as an environmental education facility (Image 8). The proximity of Rose Creek to this educational facility would increase our ability to offer in-depth native fish restoration education opportunities to interested groups.

Image 8. The Yellowstone Institute - An environmental education facility located on Rose Creek

Restoration Priority 5 – Glen Creek

Glen Creek originates on the south and east slopes of Sepulcher Mountain, crosses Grand Loop Road, and forms Rustic Falls before its confluence with the Gardner River near Mammoth Hot Springs (Figure 9). Upstream of the falls on the Swan Lake flats, Glen Creek was historically fishless. However, between 1890 and 1940, Glen Creek was stocked repeatedly with brook trout and rainbow trout. The exact locations of these stockings are unknown but it appears that only brook trout now persist. Glen Creek, above Rustic Falls, was sampled in 2007 and only brook trout were captured. Brook trout distribution in the stream was found to extend into the uppermost headwaters of the system.

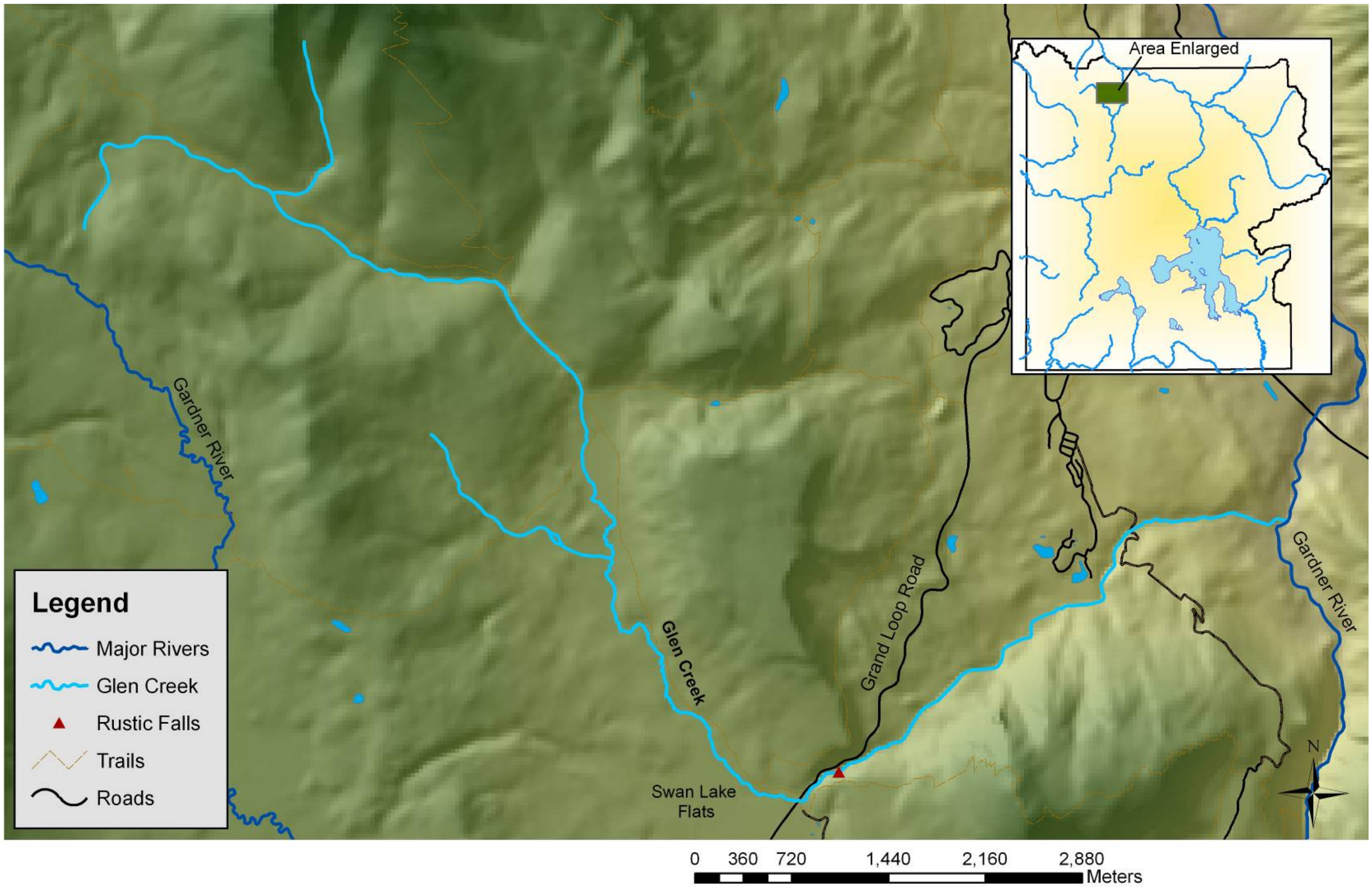

Figure 9. Glen Creek watershed and location of Rustic Falls.

Restoration Priority 6 – Blacktail Deer Creek

Blacktail Deer Creek is a large watershed in the park's North Central region (Figure 10). The system is isolated from the Yellowstone River by Hidden Falls, a 6 meter high waterfall located approximately 1.5 km upstream of the Yellowstone River. Named waters within the Blacktail Deer Creek watershed also include Little Blacktail Deer Creek, and a series of small lakes near the Grand Loop Road known as the Blacktail Ponds. Several large unnamed tributaries also exist in the system. In addition to Hidden Falls, a series of small waterfalls also exist on upper Blacktail Creek proper. Both Blacktail Deer Creek and Little Blacktail Deer Creek are part of an ongoing study on the impacts of grazing wildlife on willow and as such artificial beaver dams have been constructed on both streams. These dams may be barriers to upstream fish movement, and potentially be utilized for cutthroat trout restoration (Image 9A).

David Star Jordan's 1891 report indicates that Blacktail Deer Creek was historically home to native cutthroat trout, but, because of fish stocking from 1909 through 1943, the system above Hidden Falls is now occupied exclusively by brook trout (Jones et al. 1977). Extensive aquatic inventories have been conducted for fish, invertebrates, water chemistry, and habitat at locations throughout the drainage. However, the upstream extent of fish distribution has never been established. A YCT restoration project was attempted in the early 1980's in Blacktail Ponds. That project aimed to use a combination of stocking and changes in angling regulations to establish a population of YCT in the ponds (Jones et al. 1981). All indications suggest that the YCT did not persist and the ponds now only support nonnative brook trout.

Image 9. A) Example of artificial beaver-dam structures found on Blacktail Deer and Little Blacktail Deer Creeks. It is not known if these structures represent barriers to upstream brook trout (B) migration.

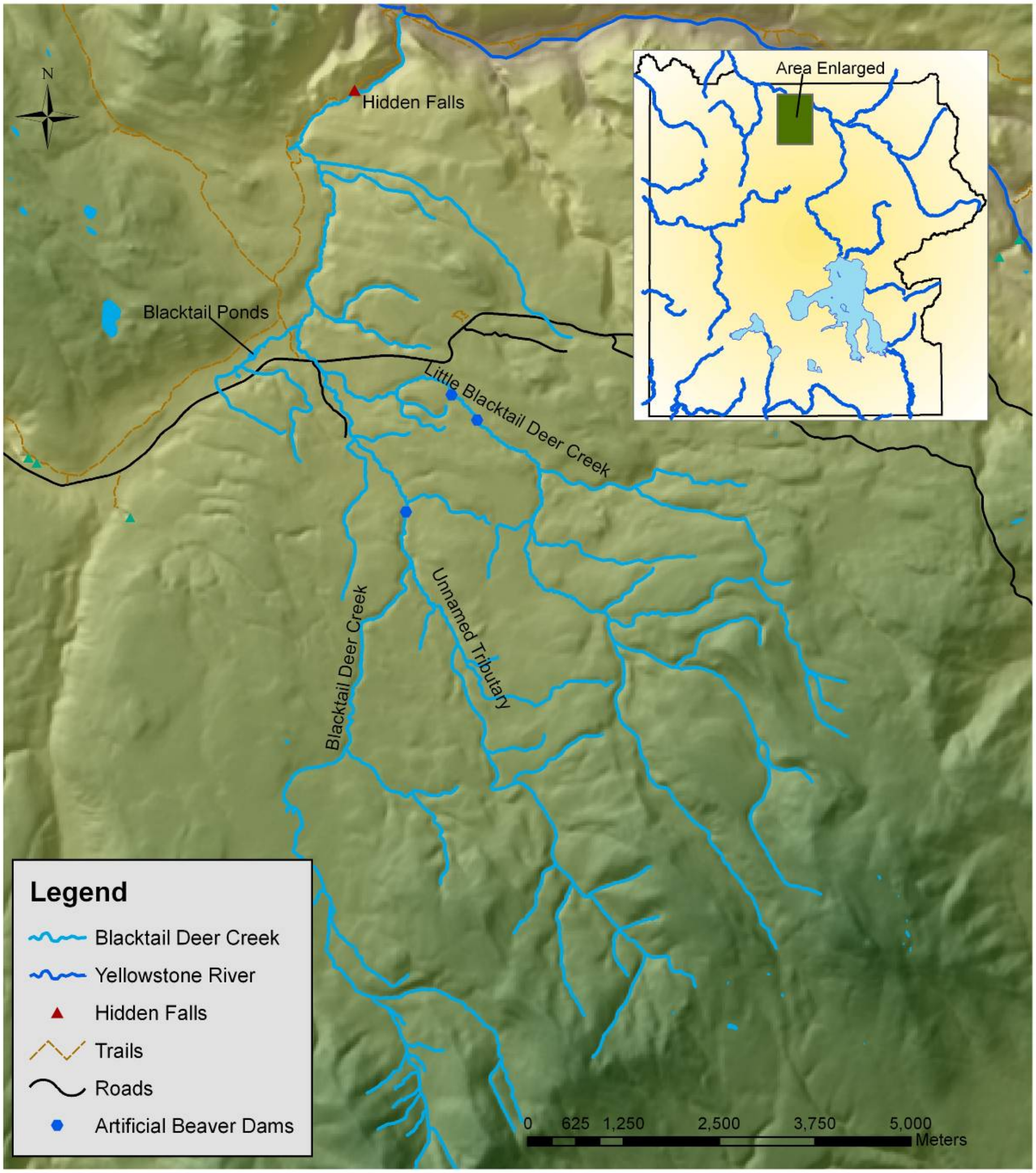

Figure 10. The Blacktail Deer Creek watershed and locations of Hidden Falls and the artificial beaver dams placed as part of an ongoing willow research project along the streams (Image 9A).

Restoration Priorities 7 & 9 – Oxbow and Geode Creeks

Historical information regarding the fishes of Oxbow and Geode Creeks were sparse at best. Both of these streams originate on the Blacktail Plateau in the Park's north central region. However, although the streams are shown as distinct watersheds on most maps, they are actually both part of the same complex, hydrologic system (Figure 11). A single stream, known as Oxbow Creek, crosses Blacktail Plateau Drive and then flows into a large wetland complex where the system bifurcates. It appears that from this wetland complex, the majority of flow is then directed toward the stream known as Geode Creek, with only a fraction of the flow remaining in Oxbow Creek. Surface flows remain through most of Geode Creek downstream to the Yellowstone River. However, Oxbow Creek has a long reach where it flows underground, including the area at Phantom Lake. Records are unclear as to the original, historical status of fish in the system, but Geode Creek was stocked with cutthroat trout of unknown origin between 1922 and 1924 (Varley 1981).

Fish are abundant in Geode Creek up to and above the wetland bifurcation, including the reaches upstream of Blacktail Plateau Drive (Figure 8B). A 2007 population estimate indicated a total population of over 13,000 fish. All fish sampled in the system have been of a very distinct cutthroat trout phenotype not typical of YCT (Image 10). Genetic analysis of these trout yielded an exciting discovery for the park, in that the fish in the Oxbow/Geode Creek complex were determined to be genetically pure westslope cutthroat trout (*O. c. lewisi*). In 2007 a definitive barrier was identified in the downstream reaches of Geode Creek near the Yellowstone River. Upstream fish distribution in the system extends into the uppermost headwater reaches, farther upstream than most maps indicate the stream being perennial, and is finally limited by a small cascade.

Image 10. Examples of WCT from the Oxbow/Geode Complex. The original source of the fish planted in Geode Creek remains unknown.

During the August 2005 sampling period, the reach of Oxbow Creek downstream of the bifurcation was small and became subsurface in the vicinity of Phantom Lake. No other tributaries to Phantom Lake could be located and the outlet of the lake and reach of Oxbow Creek immediately downstream of the lake were dewatered. Oxbow Creek downstream of Phantom Lake was explored and sampled during the early summer period of 2007. Water was found to reemerge in the stream channel approximately 0.5 miles downstream of Phantom Lake and a steep canyon reach immediately upstream from the confluence with the Yellowstone River is believed to represent a barrier to upstream fish movement. Fish, believed to be

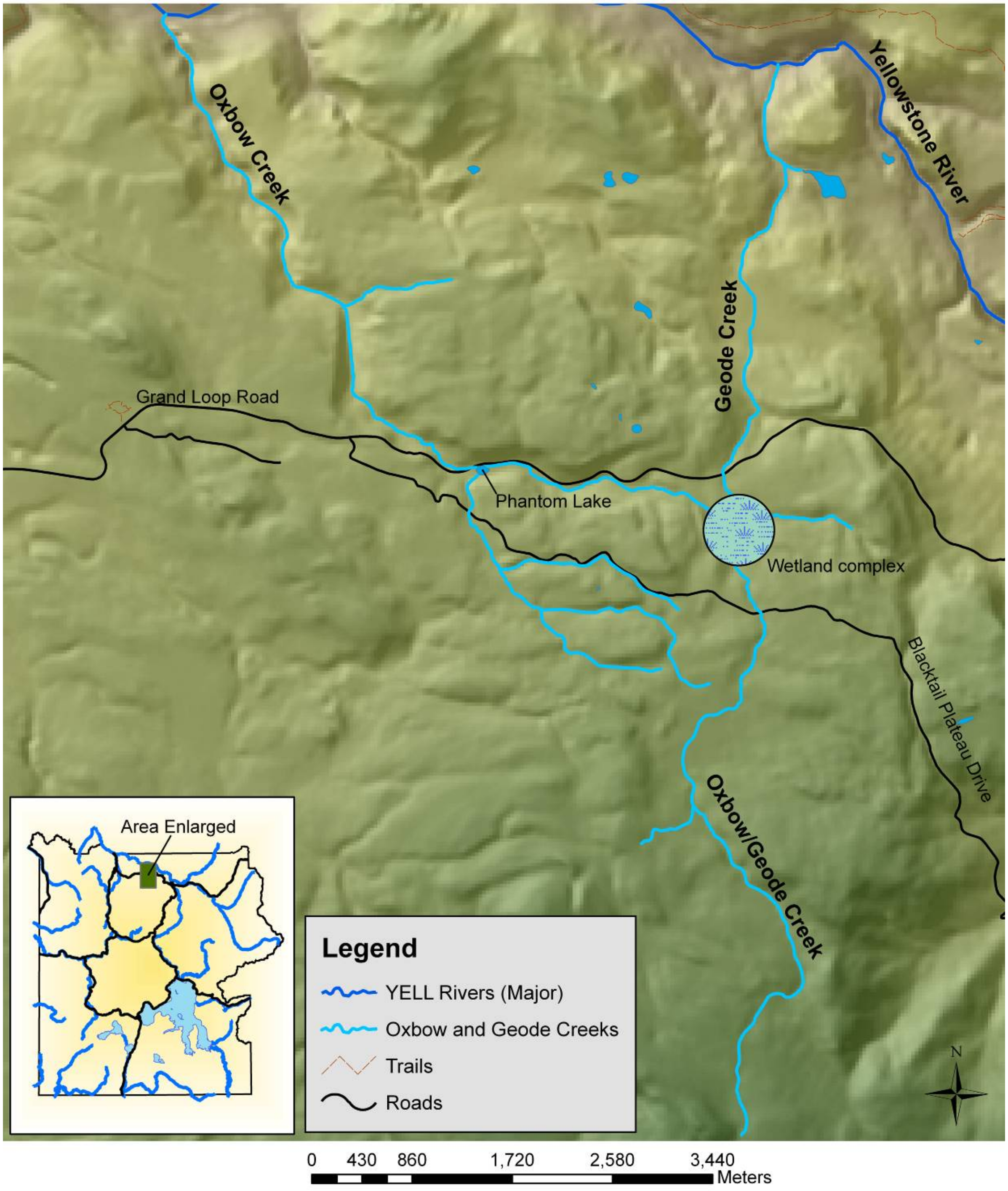

Figure 12. The Oxbow/Geode Creek Complex watershed including a wetland complex where the system bifurcates and gives rise to both streams. Current maps label the reach upstream of the wetland complex as "Oxbow Creek", but Geode Creek receives the great majority of the flow downstream of the wetland complex.

westslope cutthroat, were captured in the stream and pending analysis will reveal their genetic makeup.

The genetically pure westslope cutthroat trout population in the Oxbow/Geode Creek complex represents only the second known pure westslope population remaining in Yellowstone National Park. Because of the status of westslope cutthroat trout within their historical range in the upper Missouri River drainage, and the potential to use this population for future restoration efforts in those waters, the Oxbow/Geode Creek complex is consider a very low priority system for YCT restoration. In fact, 1150 westslope from the Oxbow/Geode Creek complex were captured and moved to High Lake via helicopter in the summer of 2007 as part of the East Fork Specimen Creek restoration project.

Restoration Priority 8 – Stephens Creek

Stephens Creek is a small stream that originates on the North slope of Sepulcher Mountain and crosses Stevens Creek Road before its confluence with the Yellowstone River downstream of Gardiner, Montana (Figure 12). Historical records indicate that Stephens Creek was not previously sampled for fish by park biologists. Sampling conducted in 2006 revealed the presence of trout in Stephens Creek both up and downstream of the road culvert at Stephens Creek Road. The fish found in the creek are suspected to be stream residents because of their observed sexual maturity at a small size. The trout from Stephens Creek strongly appear to be rainbow x cutthroat trout hybrids, and genetic analyses have confirmed that this is indeed the case. It does not appear that under normal flow conditions trout from the Yellowstone River are able to move upstream into Steven's Creek. High water years, however, may result in the system being subject invasion from nonnative fish in the Yellowstone River. Upstream extent of fish distribution in Stephens Creek is limited by three prominent barriers (Image 11A, B, & C), fish are not found above the first barrier and the second and third barriers also appear impassable.

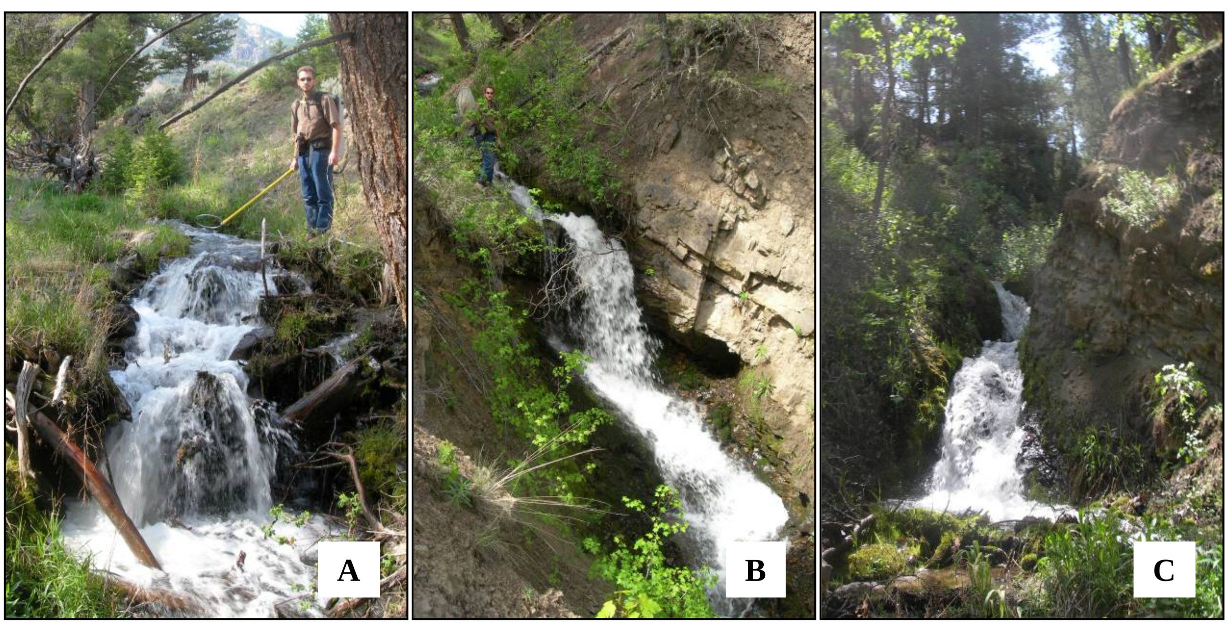

Image 11. Barriers found on Stephens Creek. The first barrier (A) is located 2.7 km upstream of the road crossing and fish are found below but not above the barrier. The second (B) and third (C) barriers are located farther upstream.

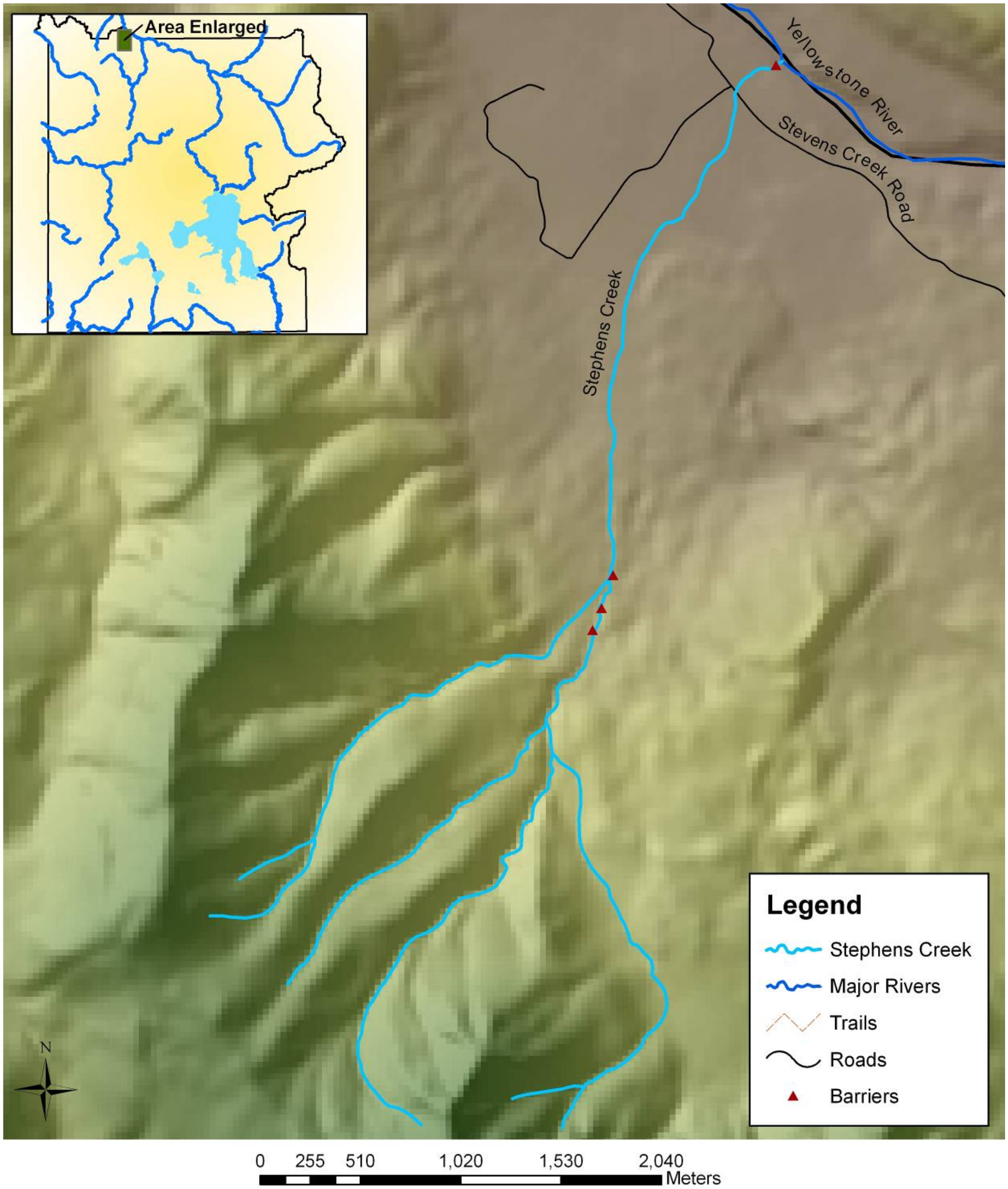

Figure 12. The Stephens Creek watershed and locations of the three barriers that limit upstream fish distribution (Images 11A, B, &C) and the barrier near the confluence with the Yellowstone River.

Restoration Priority 10 – Reese Creek

The Reese Creek watershed encompasses the North and East slopes of Electric Peak, and the stream flows northerly and meets the Yellowstone River along the park's boundary west of Gardiner, Montana (Figure 13). Reese Creek is the only stream in Yellowstone National Park where water is diverted for agriculture purposes. Three water diversion structures and associated channels exist along the streams' lower reaches. Only one of the structures, irrigation diversion #3 (Image 12), is routinely operated. This structure diverts water from the main channel of Reese Creek and directs it toward ranchlands immediately outside of the park boundary. It appears that irrigation diversion #3 is acting as a barrier to upstream fish movement. This is made evident by the fact that sampling conducted over the past twenty years has captured brown trout and brook trout downstream of the diversion, but only cutthroat trout have been found upstream of the diversion.

Image 12. The third irrigation diversion on Reese Creek. Species composition above and below the diversion indicate that it is a barrier to upstream fish movement, but electrophoretic genetic results reveal hybridization has occurred above the diversion.

Electrophoretic genetic analysis indicates that the cutthroat trout in upper Reese Creek have been hybridized by RBT most likely through upstream movement of fish from YSR before completion of the diversion (Image 13, Figure 8C). Cache Lake, at the headwaters of Reese Creek, remains fishless despite multiple attempts to establish a fish population there between 1912 and 1929 (Varley 1981). Surveys conducted in 2005 determined the uppermost extent of fish distribution in Reese Creek downstream of Cache Lake. The cumulative effect of many boulder cascades and woody debris jams within the middle reaches of Reese Creek appears to preclude fish from moving into the upper reaches of the drainage (Image 14A, B, C, & D). All of the tributaries to Reese Creek were sampled in 2005, but only Electric Creek was found to contain trout (in its lowest reaches).

Image 13. Examples of fish captured in Reese Creek above the third irrigation diversion.

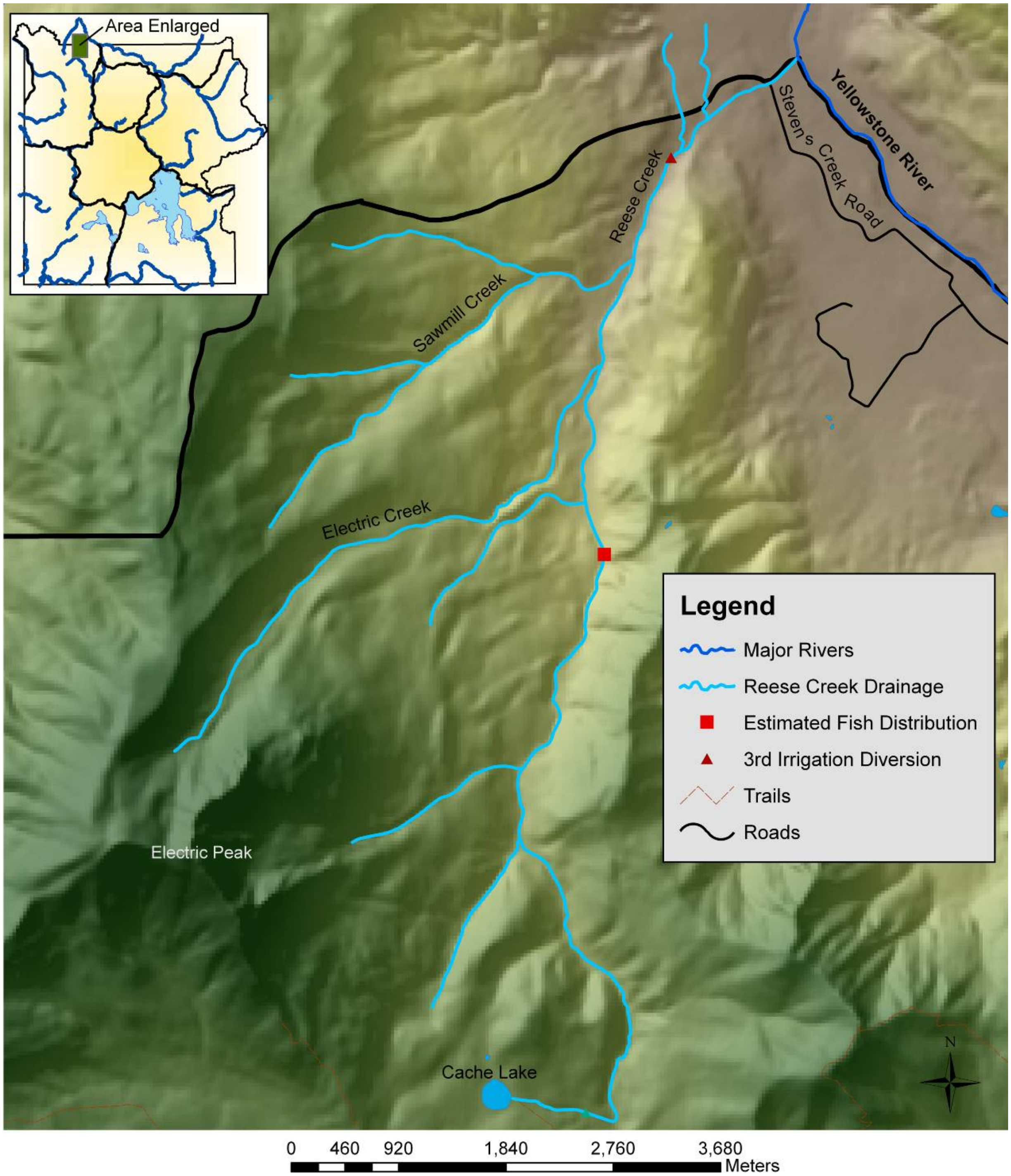

Figure 13. The Reese Creek watershed with estimated upstream extent of fish distribution, location of third irrigation diversion (Image 12) and Cache Lake (Image 14D).

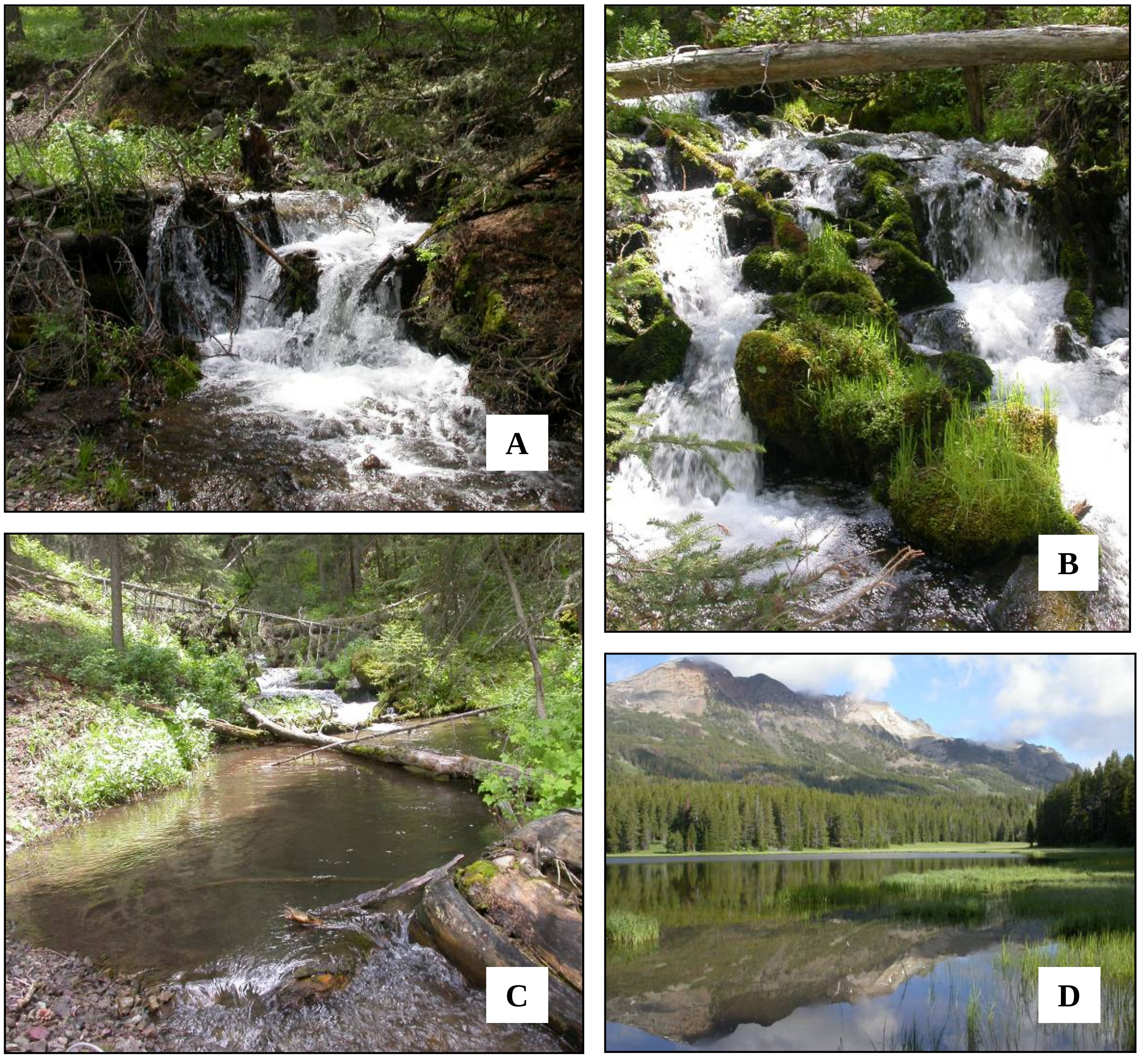

Image 14. A) Example of a log jam cascade common in upper Reese Creek; many of these features appear to be seasonal fish barriers. B) Example of a series of boulder cascades common in upper Reese Creek; many of these features appear to be seasonal fish barriers. C) Example of fishless habitat in upper Reese Creek. Despite the presence of quality habitat, typical of that found to contain fish in the lower reaches, upper Reese Creek is devoid of fish. D) Cache Lake; A fishless lake at the headwaters of Reese Creek.

DISCUSSION

Data Gaps and Stream Accessibility

Despite the abundance of data that existed for many Yellowstone waters, in depth investigations of many of the small headwater streams we incorporated into our prioritization analysis remain lacking. This is particularly true of remote waters as in most cases, the amount of information available about a given stream was related to its degree of accessibility. Modern GIS technology allowed us to circumvent many of our information gaps by allowing the capability of deriving several physical characteristics of streams including gradient, presence/proximity of wetland areas, and potential barrier locations. However, site-based data collected by field surveys remain the only way to gather chemical and biological information, critically important to our understanding of each watershed.

Lack of accessibility, which over time has resulted in a lack of chemical/biological information being collected from many backcountry streams, has unquestionably influenced the results of stream prioritization analyses presented here. It could be argued that streams with little or no road/trail accessibility make poor restoration candidates because of the extreme logistical difficulties associated with working in such remote areas. However, from the perspective of species persistence, once a native YCT population is established, these remote areas likely provide heightened security from external threats, such as introduction of disease or exotic invasive species. We believe that although areas without road or trail accessibility present a serious logistical hurdle, they should not be overlooked as candidates for large-scale restoration activities. At present, we seek to strike a balance between performing on-the-ground restoration activities in accessible locations and collecting data and preparing for restoration in previously unsampled, highly remote locations in future years.

Choosing Prioritization Parameters

Any number of parameters could have been included the prioritization matrix derived by this exercise. We do not presume that the set of parameters we chose will be equally applicable for other agencies or locations, and selection of parameters should be done with the underlying goals of the land management agency in mind. For instance, Yellowstone National Park has grizzly bear management guidelines that dictate times and types of access allowed into many backcountry areas. These rules are important to how and when our fisheries program will conduct backcountry work within Yellowstone, but the rules are not applicable to locations outside of the park boundaries. Similarly, lands outside of the park may be restricted during times when restoration activities need to be conducted because of seasonal human use, such as hunting, which is not an issue when working within the park.

Several parameters were considered but excluded because of a lack of available information for most streams. The inclusion of these parameters would add value to the prioritization analyses if sufficient data were available. Parameters including a measure of productivity (such as chlorophyll), water temperature, and pH during late summer would be especially useful for predicting restoration success within a given stream. A measure of stream productivity would allow knowledge of the potential of each stream for producing high densities and/or high growth rates of YCT. Information regarding stream temperature and pH during late summer would be particularly useful because piscicides, especially antimycin, are rendered ineffective in cold water or water with high pH (Finlayson et al. 2000).

Assessing Stream Size

Several metrics are available for assessing stream size. In compiling data for the prioritization matrix, we considered the use of watershed area, stream mainstem length, mainstem and tributary stream length, and flow (discharge) information. Ideally, mean August flow would best be used as the surrogate for stream size because it would provide the most pertinent information concerning the application of piscicides. However, flow information are non-existent or incomplete for most of the headwater streams under consideration, and collecting sufficient data for the streams would require tremendous resources. Because of this fact, we chose stream mainstem length as our stream size parameter. Previous studies (Harig et al 2000) have correlated the stream length with successful cutthroat trout restoration projects. Another advantage of using main stem length is that it provides insight into the amount of habitat under consideration. Restoration project size is often reported as linear distance of stream restored, especially for regular updates on the range-wide status of YCT.

Historic Status of Fishes in Watershed

One of the most interesting issues encountered by this work was that of the historical species composition of individual watersheds, and how that status influences a watershed's value as a restoration candidate. Essentially, five conditions currently exist in park waters:

1) Historically and currently fishless,
2) Historically and currently supporting native species,
3) Historically fishless but currently occupied by "native" species (species native to the region of the park in which the water body lies),
4) Historically native species but currently occupied by nonnative species or hybrid forms, and
5) Historically fishless but currently occupied by nonnative species.

An additional situation may exist where a historic fish population has been extirpated by a natural or artificial disturbance and has not been naturally recolonized by any species. However, no cases of historically populated and currently fishless water are known on Yellowstone's Northern Range.

At the present time, we regard situations 1 and 2 (above) as being ideal, natural conditions and, as such, they were given no considerations with regard to restoration activities. This is because historically fishless waters are given value under NPS management and stocking them is viewed as equivalent to introduction of any nonnative species. We are not inclined to stock any fish, "native" or nonnative, into any historically and currently fishless waters in the park unless it is imperative in preventing the extinction of a species and does not significantly increase the chance of extinction of any other, nontarget species. Even if this were to happen long term plans would need to include the removal of the introduced trout from these waters after successful recovery efforts were completed and the species was made secure elsewhere within its historical, native range. Stocking trout into fishless waters jeopardizes other indigenous fauna and threatens naturally functioning ecosystems (Pister 2001). Even after removal of trout from historically fishless systems, pre-disturbance conditions may not return without additional restoration efforts (Drake & Naiman 2000).

In historically fishless waters where native species have been introduced within their natural, historic range (situation 3 above), we are not currently considering any restoration actions. The current status of YCT in Yellowstone mandates that we conserve YCT populations *if they exist within the regions where they were historically found.* If genetically pure YCT were restored to most of their historical range within the park, efforts to remove introduced populations from historically fishless waters within this range could be considered.

The ideal waters for performing native species restoration are where genetically pure YCT have been replaced by a nonnative species or a hybrid form. Projects in places of this nature would be the least (ecologically) controversial. We assigned higher priority to streams where nonnative species have nearly or completely replaced native populations than streams where native populations have become hybridized. This was done because of the controversy that surrounds the degree of hybridization and its relevance to native cutthroat trout conservation and restoration efforts (Allendorf et al 2005, Campton & Keading 2005). Simply put, the debate is over how much genetic introgression is acceptable and at what point hybridization negates a population's conservation value. Opinions on the subject range widely, but the USFWS defines populations with less than 10% introgression as "conservation populations," those having attributes worthy of conservation (USFWS 2006).

The most interesting situation we encountered in compiling this report regarded historically fishless waters that are currently occupied by a nonnative species, including hybrid forms of cutthroat trout. Specifically, if nonnative fishes are removed from waters that were historically fishless, is it appropriate to establish "native" fishes in their place? The issues that surround performing restoration in these areas are both ecological and anthropocentric, and consideration of both is necessary for practical decision making. Many Yellowstone waters, such as Lava Creek, were stocked with fish shortly after the Park's establishment and have supported reproducing trout populations for over a century. The initial reason for stocking fishless waters was to provide recreational opportunities, and numerous important recreational fisheries exist today in historically fishless waters. The proposed removal of fish from an area popular with recreational anglers without subsequent restocking could be controversial, and may not currently be feasible even in a national park. This seems especially true when the removal is not tied to a specific recovery plan for a threatened or endangered species. From a recreational perspective, maintaining a fishery is desirable, and this position must be considered in the context of the park service mandate.

Moving Forward with the Yellowstone Cutthroat Trout Restoration

This report represents completion of Phase I of the Northern Range cutthroat trout restoration effort. The prioritization matrix produced by this phase of the initiative has allowed us to select several streams for restoration action. Three stream systems have been selected. The Elk Creek Complex (Elk, Lost, and Yancey Creeks) and Rose Creek have been chosen as sites to undergo complete removal via piscicides and reintroduction of genetically pure YCT. Additionally, Reese Creek has been selected as a location to undergo YCT restoration through a combination of mechanical fish removal and genetic swamping (stocking of genetically-pure YCT).

Selection of locations for on-the-ground restoration activities allows for movement into the second phase of the program. Phase II will involve completion of a NEPA compliance process that considers multiple watersheds in the park. Other documentation processes include NPS Pesticide Use Plans (PUPs) and a variety of state and federal permits required to build fish barriers and apply piscicides. Conducting on-the-ground restoration activities will represent the third and final phase of the Northern Range cutthroat trout restoration effort.

CONCLUSIONS

Our primary goal is to return native cutthroat trout to their native habitats, which did not, originally, include many waters in the park. However, we chose to include historically fishless waters that are currently occupied by nonnative trout or hybrid cutthroat trout in our group of candidates for stream restoration. Doing this, however, begs the question of how one should define native trout restoration within Yellowstone. Establishing native fish populations in originally fishless waters may help to ensure the species is more resistant to extinction by augmenting the number of populations that exist, but the practice otherwise is myopic in that it ignores other ecosystem aspects of true watershed-level restoration. Restoration should focus on returning natural ecosystem function to individual watersheds and reversing a trend of nonnative species invasion. We acknowledge that restoring a drainage to native-species-only status does not necessarily mean a return of pre-disturbance conditions; in fact, elements of restoration, such as placement of an artificial fish barrier, may impede natural ecosystem function, but each project should be viewed as a step towards larger-scale restoration. That is, by fragmenting habitats through barrier construction in the short-term, we may be able restore larger systems in the long term.

Restoring ecologically significant populations of YCT to Yellowstone’s Northern Range will be a long process requiring public support, fiscal commitment, and sound science. The Fisheries Fund Initiative of the Yellowstone Park Foundation, and resulting completion of Phase I of YCT restoration across the Northern Range, represents a positive step forward for native fish restoration in Yellowstone National Park. By synthesizing existing data, directing new data collection, and initiating stream level restoration projects, this work provides a clear pathway towards YCT recovery in Yellowstone’s Northern Reaches into the foreseeable future. The success of the Northern Range effort will not only be measured by the number and size of YCT populations reestablished, but also by the ability to both educate the public on native fish restoration and demonstrate that projects of this nature are compatible with, and beneficial to, the enjoyment of their park.

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ACKNOWLEDGEMENTS

Special thanks to the Yellowstone Park Foundation for their long standing support of Yellowstone's unique fisheries and for making the YCT restoration across the Northern Range possible through the fiscal commitment of the Fisheries Fund Initiative. We also acknowledge the hard work and dedication of the technicians and volunteers who have committed their time and efforts to improve the status of native fishes in Yellowstone. We would like to thank Matt Campbell, geneticist for the Idaho Department of Fish and Game for his cooperation in performing genetic analyses. We are especially grateful for the patience and skill of Hilary Billman as she edited and provided constructive comments on earlier versions of this document.