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Evaluating the Effect of the Removal of Non-Native Trout in Two High Elevation Tributary Streams in the Intermountain West

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EVALUATING THE EFFECT OF THE REMOVAL OF NON-NATIVE TROUT IN TWO HIGH ELEVATION TRIBUTARY STREAMS IN THE INTERMOUNTAIN WEST

By

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A capstone report submitted in partial fulfillment of the requirements for the degree

of

MASTER OF NATURAL RESOURCES

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ABSTRACT

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by

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Utah State University, 2020

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Native fish species such as Bonneville Cutthroat Trout (BCT) require cold, clear, well-connected streams for spawning and rearing as well as access to complimentary habitats. Increasing river temperatures and lower water flows may have allowed non-native Brown Trout (BNT) to migrate into higher elevation pristine streams. Additionally, anthropogenic actions such as stocking non-native Brown and Brook (BKT) and Rainbow Trout (RBT) for angling opportunities impact BCT. Invasion of these tributaries by non-native species may reduce or eliminate cutthroat trout by predation, competition, displacement, genetic suppression, and exclusion. A seven-fold increase in BNT numbers of 50 to 350 from 2017 to 2018 demonstrated the need for this research. The goal of this project was to assess the density and distribution of non-native BNT and BKT, conduct a complete mechanical removal of BNT and BKT, and reconstruct the history of the expansion of BNT and BKT in the Temple Fork and Spawn Creek tributaries

of the Logan River, UT, USA. In order to meet this goal we used pre-existing sampling data, conducted removal efforts on Temple Fork and Spawn Creek, and analyzed historical data of when BNT and BKT first appeared in sampling efforts in these locations. Our sampled locations were 400m to 500m in length on Temple Fork from the confluence with Logan River and also on Spawn Creek. We identified all captured fish and BNT and BKT were removed. We observed a surprisingly high number of BNT (2,551) and BKT (566). We did not observe BNT above reach 9 on Temple Fork and reach 6 on Spawn Creek. We were encouraged to find high numbers of BCT though BNT numbers have been increasing as previously mentioned. We demonstrated by capturing 6 BNT that a permanent selective barrier at the confluence of the Logan River and Temple Fork was not be necessary to prevent the high numbers of brown trout from invading this tributary each fall to spawn. A second trapping effort with the picket weir may further help identify movements of BNT (Figure 11). While immigration of BNT into Temple Fork from the Logan River may contribute BNT in the lower reaches of Temple Fork, ultimately the establishment of a resident population of BNT and BKT threaten to overwhelm BCT. Further actions such as additional mechanical removal efforts every other or every third year and fishing regulation changes may be warranted to protect BCT from further invasion throughout this tributary, range-wide, and where native fish populations struggle from similar concerns.

(62 pages)

ACKNOWLEDGEMENTS

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Introduction

Around the world invasive species such as rabbits, rats, phragmites, Lionfish, and bullfrogs have wreaked havoc on native flora and fauna. Humans have transported non-native species both intentionally for food, habitat, or unintentionally while travelling across oceans or continents. Brown Trout *Salmo trutta* (BNT), were stocked from Europe to every continent except the Antarctic beginning in the late 1800s (Maccrimmon and Marshall 1968). These introductions were mainly for food purposes as human populations started to grow. Subsequent introductions were for angling purposes. Currently BNT were listed as one of the "100 World's Worst Invasive Alien Species" (Lowe et al. 2000; Westley and Fleming 2011). In New Zealand, BNT have decimated native galaxiid fish species (McIntosh et al. 2010). In an effort to slow further invasion of BNT into native fisheries, state and federal agencies have increased their efforts by encouraging increased angler harvest, mechanically removing BNT, or chemically treating fisheries to restore native fishes. This research focused on a mechanical removal effort on the Logan River in northern Utah.

The Logan River and its tributaries, Temple Fork and Spawn Creek, Right Hand Fork, and Beaver Creek provided critical habitat for spawning and rearing of native fluvial Bonneville Cutthroat Trout *Oncorhynchus clarki utah* (BCT), as well as habitat in general for Mountain Whitefish *Prosopium williamsoni* (MWF), and Mottled Sculpin

Cottus bairdii. The tributaries were of particular importance because BCT were naturally limited by the availability of low velocity spawning habitat with abundant suitable gravel (Budy et al. 2012). The Logan River and its tributaries were unique and this watershed supported the densest population of BCT throughout the entire range of the species, and the BCT were genetically pure (Budy 2006). This highly viable population of BCT was due largely to the large amount of nearly pristine and connected habitat. Cutthroat trout required cold, clean and well connected streams, such as those in the Logan River system, to thrive. Natural reproduction produced hundreds of thousands of BCT fry each year in the Logan River and its tributaries. This annual reproduction was critical to the recruitment of BCT, which sustained this stronghold population in the Logan River.

Introduced Brook Trout *Salvelinus fontinalis* (BKT), Rainbow Trout *Oncorhynchus mykiss* (RBT), and BNT also occurred in these streams and have repeatedly impacted native communities through competitive exclusion, displacement, and predation (L'Abée-Lund JH 1992; Mooney and Cleland 2001; McHugh et al. 2006; Meredith 2012).

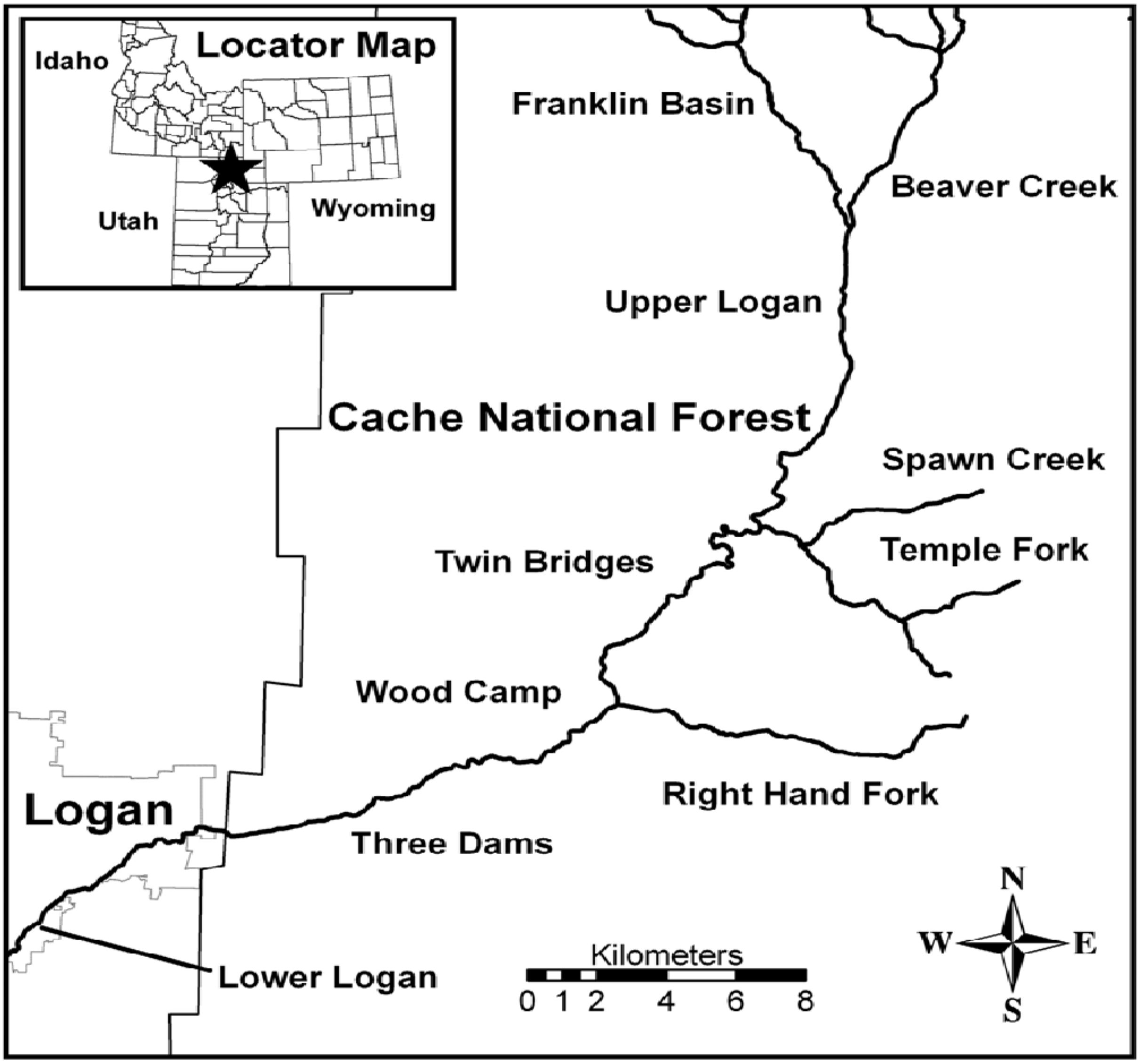

Figure 1. Logan River and its tributaries. Map taken from Wood 2008.

The Logan River was classified as a Blue Ribbon Fishery by the UDWR. Fishing for BNT, BCT, RBT and MWF was very popular. In 2017, USU, United States Geological Service (USGS), Utah Cooperative Fish and Wildlife Research Unit (UCFWRU), TU, and UDWR, funded and implemented an angler creel survey from First Dam to the Idaho border on the National Forest. A total of 446 angler interviews were conducted over 59

survey days from July through October. The river and its tributaries were extremely important to those who lived locally. Ninety one percent of all anglers were from Utah. Fifty six percent were from Cache Valley, and 42 percent from Logan specifically. The fish most often caught were BNT, BCT, and MWF respectively. Six percent of all anglers surveyed specified BNT as their target species, and five percent targeted BCT; however most anglers preferred no specific species. Fifty two percent of all anglers were not aware the Logan River population of BCT was one of the densest in its’ range. Another question noted that an irrigation reservoir has been discussed to be built on Temple Fork. A reservoir in this location would eliminate all reproduction of BCT and prevent all fish movement from the Logan River and into Temple Fork. Eighty seven percent of all anglers were not aware of this proposed dam. Overall, the Logan River and tributaries were an extremely important part of Cache Valley and surrounding counties in Utah (Logan River Creel Survey, UDWR, 2017). A socioeconomic report was still pending from the survey. Furthermore, we still have more to learn about this wild native fishery was tied to the long lasting benefits of health, aesthetics, wildlife values, and the role it played for residents of this valley for example.

The Right Hand Fork (RHF) of the Logan River established population densities over 4,000 BCT per mile based on sampling efforts in 2018 by Utah Division of Wildlife Resources (UDWR), and all age classes were present from age 0 to age 6 in this sampling effort. Right Hand Fork had few BCT prior to 2010. This population increase resulted from multi-year restoration efforts from 2010 to 2014. Restoration efforts included mechanically removing BNT and chemically treating RHF. Two separate natural and

concrete barriers were bolstered and/or installed in 2010 and 2014, respectively. The barriers kept BNT from reestablishing within RHF. Stocking of fingerlings and egg baskets over two more years finished the project. This restoration effort was important to the overall BCT population, given the importance of tributaries and prior to the restoration, RHF was completely dominated by a very dense sub-population of brown trout and was a likely source to the lower river (Saunders et al. 2014). Each spring these tributaries add more cutthroat trout to the lower Logan River as densities increase and spring flows flush small fish downstream into the river.

Utah State University (USU) has conducted fish population estimate surveys in the Logan River and its tributaries since 2001 with support from UDWR and the USFS. They sample specified reference reaches of this watershed as part of Fish Diversity (WATS 3110) and other classes. Annual monitoring efforts have provided researchers and fishery managers with nearly continuous trend data which highlighted the importance of this meta-population of BCT in Temple Fork and Spawn Creek. The long-term data appear to indicate an expansion of BNT within the Logan River, into Temple Fork and Spawn Creek, with BNT numbers increasing significantly from 2013-present (Budy and Thiede 2018). There were anecdotal accounts of this pattern happening in the past.

In August of 2018, USU notified UDWR of increasing populations of brown trout. In their 2017 sampling attempts, USU sampled approximately 50 individual BNT at their reference sampling location in Temple Fork. In 2018, the same reference location produced approximately 350 individual BNT; a seven-fold increase in abundance.

Evidence suggested it was more difficult for BNT to expand their numbers and establish when cutthroat trout were present in high densities (Cerviá et al. 2018; Saunders et al, in progress). Unfortunately, recent capture data showed BCT numbers in Temple Fork have decreased at the same time BNT have expanded their range and numbers in Temple Fork. Randall (2012) discovered BNT in the lower portions of Temple Fork and Spawn Creek and BKT in upper Spawn Creek (Figures 2-3).

This sudden increase in BNT numbers was concerning, and led to a dialogue between USU, DWR, USFS and Trout Unlimited (TU) regarding possible actions to address the changing fish community in Temple Fork. The robust population of BCT in the Logan River was potentially threatened by the invasion of BNT into Temple Fork. Targeted efforts such as mechanical removal of non-native fish (e.g. BNT, RBT, and BKT) was also identified in the recent Bonneville Cutthroat Trout Range-Wide Conservation Agreement and Strategy (Lentsch 1997, BVCT State of Utah Conservation Team 2008, Oplinger and Birdsey 2018, Peterson JT et al., 2004).

The goals of this study were to: 1) better assess the density and distribution of non-native BNT and BKT in Temple Fork and Spawn Creek, 2) complete a mechanical removal of all captured BNT and BKT, and 3) reconstruct the history of BNT and BKT presence and expansion into Temple Fork, to better understand the factors associated with their expansion (e.g., drought, density).

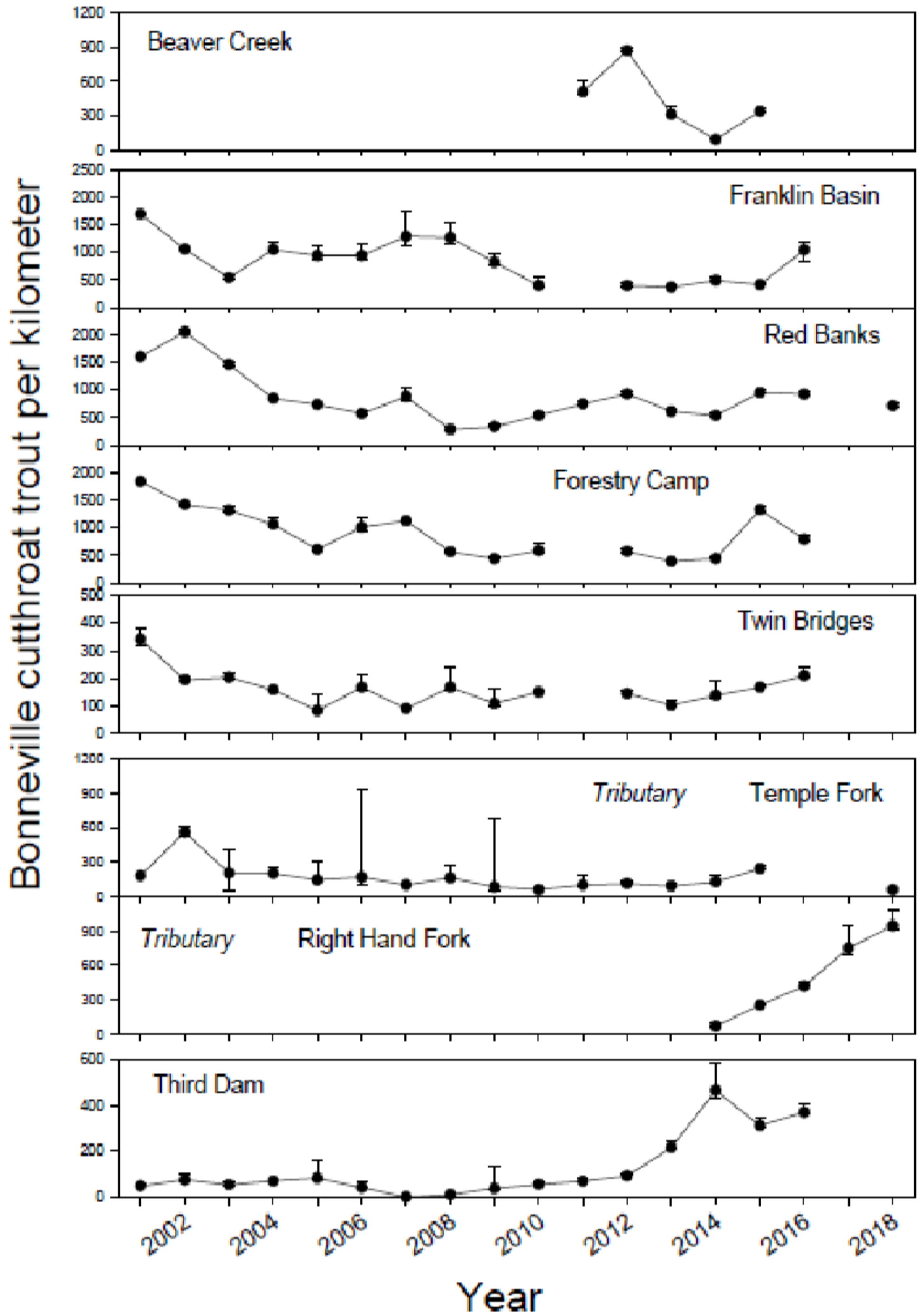

Figure 2. Population estimates (± 95% confidence intervals) for Bonneville Cutthroat Trout at eight index sites on the Logan River and its tributaries based on estimators in Program Mark, 2001-2018. Not all sites were sampled every year. Note dramatic changes in y-axis scales (Budy 2018).

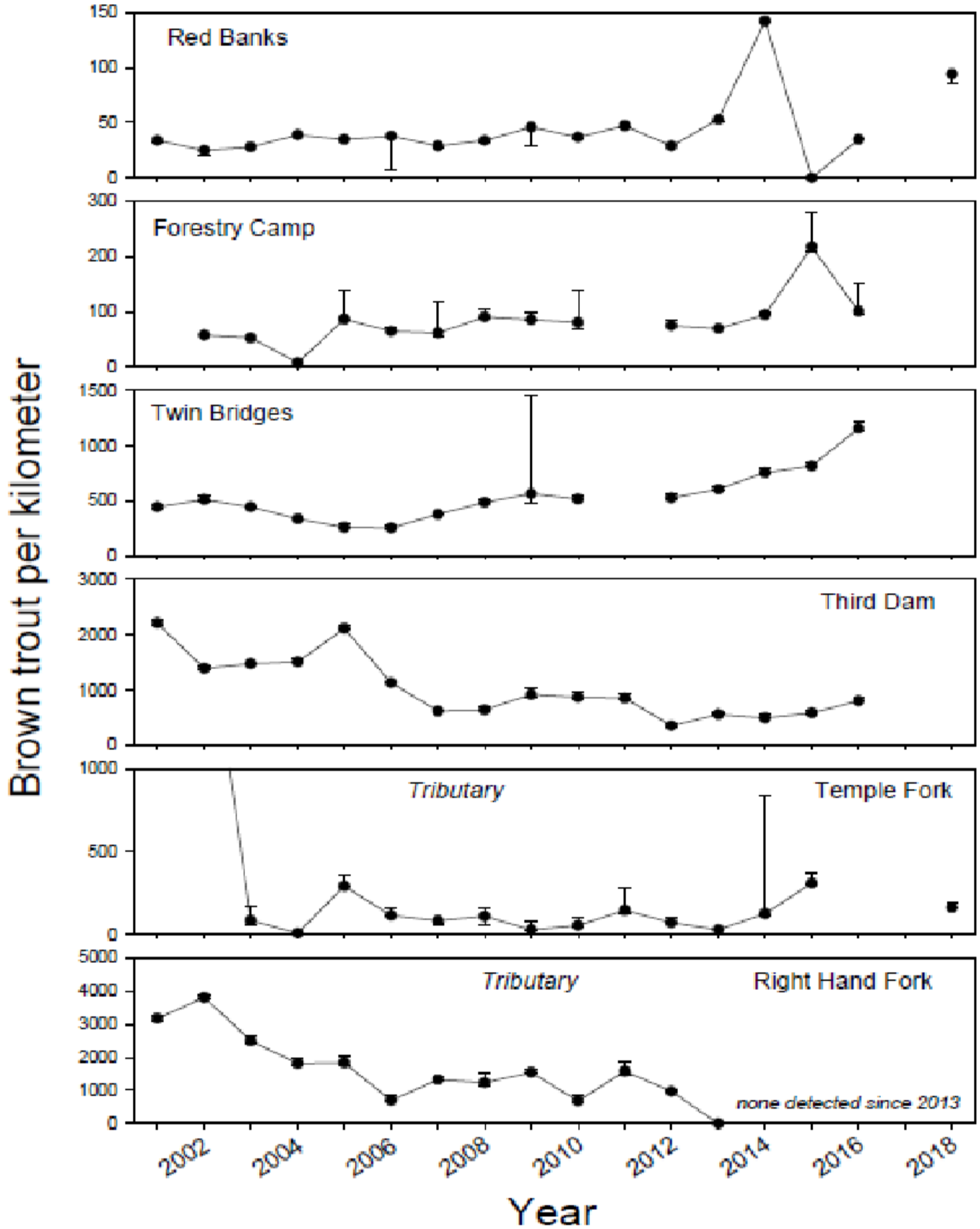

Figure 3. Population estimates (± 95% confidence intervals) for Brown Trout at six index sites on the Logan River and its tributaries based on estimators in Program Mark, 2001-2018. Not all sites were sampled every year. In 2001-2002, Temple Fork densities exceeded 2000 Brown Trout per km. Note dramatic changes in y-axis scales (Budy 2018).

Methods

The study area (Temple Fork tributary) was located 27.5 km upstream from the city of Logan UT, USA, on the Logan River (Wood 2008). The Logan River and its tributaries used by BCT were primarily located on United States Forest Service (USFS) property starting in Idaho and flowing into Utah within the Wasatch-Cache National Forest (Figure 1). The Logan River flows 86 km from Idaho South and West into the Bear River at Cutler Reservoir in Cache County, Utah. Temple Fork and its tributary, Spawn Creek, were an extremely important tributary to the Logan River for spawning native BCT. We identified 400m to 500m reaches of stream starting at the confluence of Temple Fork and Logan River. Reaches were marked with chartreuse flagging tape and labeled with the number of the reach and orientation (i.e. top or bottom) along with UTM waypoints. We separated and numbered each reach and the total numbers of captured and removed BNT and BKT were recorded. We imported the reach locations into GIS and constructed a density plot to show distribution of trout throughout the tributary with the densities of BNT and BKT in each reach in the system. This map of relative density provides a basis for understanding how Temple Fork was used by BNT and BKT.

We started by conducting annual fish sampling in August 2019 in reference locations with USU. We measured all BNT and BCT by total length, weight, and location. We entered the data into a spreadsheet and saved as a .csv file to import into Program R. The following histograms, charts and graphs were part of the analysis of the data

collected. Histograms allowed a quick assessment of the data based on the length of the fish and the number of each sized fish.   We used the lengths of all fish collected and analyzed the data using length frequency histograms.

Each crew sampled several reaches beginning with the lowest reaches and proceeding upstream. Where possible, reaches began and ended at an obvious marker, such as road, fence, trail crossing, or large beaver dam. This facilitated crews easily identifying the start or end of a reach. Each reach was electrofished using backpack electrofishing units. Electricity from a small 12 volt battery was transmitted into the water via Smith-Root 12A, 24, and 20 model backpack electrofishing units utilizing 150-300 V, 45-60 Hz, and 0.5-1.0 A based on similar research(Saunders et al. 2014). Fish within the effective field of electricity were temporarily stunned and catchable. Crews collected as many fish as possible in each reach. Crews of one biologist or an experienced technician led a crew of three to four more individuals. Each crew sampled a designated reach. We collected and identified fish to species. Brown Trout and BKT were removed from the population, length and weight was recorded and placed in a cooler on ice where they were cleaned, filleted, and dropped off to the local food pantry to be distributed. Cutthroat Trout were examined for an adipose fin clip. If the adipose fin was missing, the fish was placed in a bucket with water and length, weight, were recorded and then scanned for a Passive Integrated Transmitter (PIT) tag. All BCT were released into the reach where they were sampled.

We evaluated the condition factor, Fulton's K, on the data collected by USU from 2010 to 2019 on BNT age classes 1 and 2 (Budy et al. 2008). The size limits for age 1 and

2 were 100 m to 179 mm and 180 mm to 259 mm. Based on our histograms our age 1 fish were 110 mm to 199 mm and the age 2 fish were 200 mm to 279 mm. Wood also discussed age 2 as fish over 200 mm (Wood 2008). We used the August removal effort data as a comparison since USU sampled in late July and early August in Temple Fork and Spawn Creek each year, if possible. We expected with an increase in BNT numbers the condition of BCT would have changed over time. We used the following equation for Fulton's K (Cerven 1973; Budy et al 2003):

$$K = (W/L^3) \times 10^5$$

We stratified by age class, stream (Temple Fork or Spawn Creek), species, and year. Some years had fewer than 10 fish collected per age class or stream. We combined the years into three groups for each stream: early (2010 to 2012), mid (2013 to 2015) and late (2016, 2018 and 2019). Data was not collected in Temple Fork or Spawn Creek in 2017.

Additionally, the picket weir (fish trap) was installed into Temple Fork on 23 September, approximately 90 meters upstream from the confluence of the Logan River and Temple Fork. A long shallow pool with a flat bottom was selected for installation and the location provided easy to access for installation, maintenance, checking, and removing. We placed two traps within the weir. One trap pointed upstream to capture fish leaving Temple Fork. The other faced downstream to capture fish entering Temple Fork to spawn. Brown Trout were not released and we did not capture any BCT. Documenting the quantities and timing of fish movement dictated the efficacy of either

yearly mechanical removal of BNT and BKT or installing a barrier to prevent further expansion. We manned the weir by volunteers from Cache Anglers, TU, technicians, and USFS. Working with USU, we compiled historical BNT data for Temple Fork and attempted to determine if trends in abundance were associated with environmental or other biological factors.

Prior to reach determination, we fished Temple Fork during July 2019 to determine the distribution of brown trout. During this trip we observed only BCT upstream of a large beaver dam. The top end of reach nine came from this evaluation. Fish collected during that trip were BCT and released. We designated nine reaches on Temple Fork and six reaches on Spawn Creek (Figure 4). Each removal effort reduced BNT and BKT numbers in the short-term and ensured BCT maintain Temple Fork as a population stronghold and source for new BCT recruits in the Logan River.

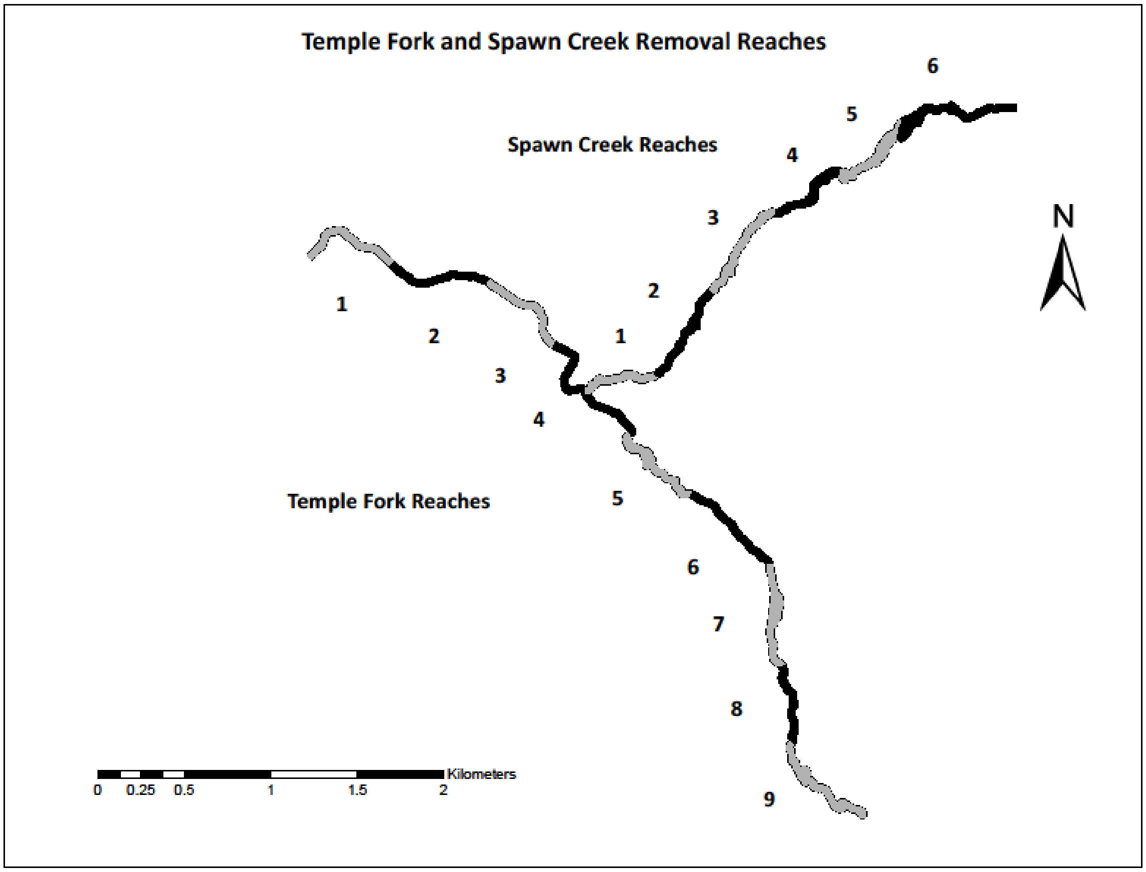

Figure 4. Map of study area. Temple Fork (TF) and Spawn Creek (SC) reaches labeled. There were nine reaches in Temple Fork and six reaches in Spawn Creek. We sampled 10,090 meters or 6.27 miles during each removal effort. Study area sampled during the period 21 August - 5 December 2019.

The first removal effort for BNT and BKT occurred mid-August with the help of USU, UDWR, TU, USFS, and volunteers. The final removal effort concluded in mid-September after a weir was installed near the confluence of Temple Fork and Logan River. On 23 August, a large group of fisheries biologists, technicians, professors, and volunteers gathered at the main parking area for Temple Fork off U.S. Highway 89. We divided into three crews, each crew was assigned three reaches on Temple Fork and two reaches on Spawn Creek. Each crew sampled the lowest reach on Temple Fork the first

morning, worked upstream and collected as many brown trout and cutthroat trout as possible. There were no BKT present in Temple Fork. The robust woody riparian vegetation increased the difficulty in collecting fish. Each crew kept all brown trout and only those cutthroat trout with a fin clip. All BCT were released during this collection effort.

In addition to the removal efforts in August and September, spawning removals for BKT and BNT occurred in November on Spawn Creek and Temple Fork. This was an additional effort to reduce adult non-native fish and their progeny. We based our initial hike on professional knowledge and from data gathered (Beard 1991, Meredith 2012, Petty 2005). On 8 November, 2019, we parked at the trailheads for both tributaries and hiked upstream looking for spawning fish on redds or spawning activity. We were unable to locate redds or spawning fish on Temple Fork and hiked to the top of reach 9. We hiked Spawn Creek and specifically looked at the small gravels where flows entered beaver ponds. This seemed like a suitable area to find spawning fish. We observed spawning BKT and BNT in reaches 4-6. We returned to Temple Fork on 14 November, for a removal effort.

Results

Temple Fork removal effort

We removed in excess of 2,500 BNT and 500 BKT from the Temple Fork drainage in two removal efforts, subsequent spawning efforts and the fish trap. We removed a total of 795 BNT during our first pass. We removed an additional 468 BNT on the

second pass. Additionally, we captured BCT during both passes 204 and 232, respectively. All BCT were released during the removal efforts. Both efforts combined to total 479 hours of effort to remove non-native fish from Temple Fork.

A spawning removal in Temple Fork effort occurred on 14 November, and 21 BNT were collected from spawning redds and in large pools adjacent to spawning gravels being used (Meredith 2012). Temple Fork contained the picket weir (fish trap) in reach 1 approximately 90 meters upstream from the confluence with the Logan River. A total of six BNT were trapped and euthanized after trapping. This weir was operated from 23 September to 5 December 2019. These 6 BNT were included into overall removal efforts. Our Temple Fork removal effort hours and fish collected for Temple Fork (Table 1).

Table 1. Removal numbers of Brown Trout and Brook Trout in Temple Fork tributary. *Bonneville Cutthroat Trout were not removed from the stream but released back into the reach sampled. Hours of effort indicates the hours of effort to remove fish between both passes for all those who helped. Spawning removal refers to the fish removed during the date listed. Trap refers to the fish trap and fish caught in the trap from September 23 to December 5 2019.

Temple Fork	**Date**		
	21-23 August	**24-25 September**	
Species	**Pass 1**	**Pass 2**	**Hours of Effort**
BNT	795	468	479
BKT	0	0	
BCT*	204	232	
Spawning Removal	**14 November**	**Trap**	
BNT	21	6	

Spawn Creek removal effort

Spawn Creek required 336 hours of effort to remove in excess of 1,000 BNT and 500 BKT. We removed 766 BNT on our first pass and 439 on our second pass. We removed a total of 358 and 151 BKT from our first and second passes respectively. Additionally, we removed another 56 BNT and 57 BKT from Spawn Creek on 9 November, when we sampled for spawning fish. We did collect and release 66 BCT on the first pass and 13 BCT on the second pass (Table 2). All BCT were released and only data was recorded on those with an adipose fin clip, indicating previous tagging.

Spawn Creek was much narrower in width and contained many more beaver dams. Average width on Spawn Creek was 1.45 meters wide compared to Temple Fork at 3.86 meters wide. This was similar to data collected in other research (Budy 2012). Electrofishing narrow streams with tight riparian woody vegetation was difficult. Higher densities of beaver dams also increased the effort required per reach. There were 17.6 beaver dams per kilometer on Spawn Creek in comparison to 3.70 beaver dams per kilometer in Temple Fork. Spawn Creek was historically stocked with BKT in the highest elevations (UDWR 1965). A natural rock barrier to fish passage was previously located in past sampling efforts by USFS. This natural barrier kept BKT from moving upstream. USFS biologists transplanted surplus BCT from the Right Hand Fork restoration project above the barrier in 2014. The sampling efforts during our work verified BCT above the barrier and that no BKT were present. Additionally, during the 9 November spawning removal effort, the crew surveyed the pool directly below the barrier specifically to check for the presence of BKT in the pool. Brook Trout discovered in this pool could move above the barrier due to a large beaver dam which raised the pool level and

limited the effectiveness of the barrier. All shocking efforts revealed only BCT in the pool.

We knew BKT were present in Spawn Creek but did not know the densities of BKT. We decided to remove BKT as part of the overall non-native trout removal on Temple Fork drainage. A smaller population of BKT was present in reach 5 of Spawn Creek, and a very robust population of BKT was present in reach 6 up to the natural barrier. On 8 November, we hiked Temple Fork and Spawn Creek searching for spawning BKT and BNT. Zero spawning fish were present on redds in Temple Fork. We did observe spawning fish from reaches 4-6 on Spawn Creek. A crew was organized, and we removed 113 fish on 9 November. The results from both August and September removal efforts as well as the November spawning removal effort were shown. All removal effort hours for August, September, and November were also included (Table 2).

Table 2. Removal numbers of Brown Trout and Brook Trout in Spawn Creek tributary. *Bonneville Cutthroat Trout were not removed from the stream but released back into the reach sampled. Hours of effort indicates the hours of effort to remove fish between both passes for all those who helped. Spawning removal refers to the fish removed during the date listed.

Spawn Creek	**Date**		
	21-23 August	**24-25 September**	
Species	**Pass 1**	**Pass 2**	**Hours of Effort**
BNT	766	439	306
BKT	358	151	
BCT*	66	13	
Spawning removal	**9 November**		30
BNT	56		
BKT	57		

Temple Fork drainage removal efforts

Thirty eight percent (969) of all BNT captured were young of year (YOY) or smaller than 100 mm. The numbers of fish, species, and the amount of effort per stream and in entirety were illustrated in the following table. Our efforts in August removed 1,919 BNT and BKT. The September effort removed 1,058 BNT and BKT from both tributaries. Spawning removals added another 140 BNT and BKT from the streams. We removed a total of 3,117 BNT and BKT through all the efforts of August, September, November and the fish trap. A total of 932 hours from biologists, technician, and volunteers was indicated in Table 3. Additionally, the cost of time was multiplied by $20.00 per UDWR guidelines.

Table 3. Removal numbers of BNT and BKT in Temple Fork drainage. * BCT were not removed from the stream but released back into the reach sampled. Total fish removed indicates totals for each species removed throughout the drainage. Removal effort hours represent the total hours dedicated towards fish removal by electrofishing. Trap hours represents the hours dedicated to checking and maintaining the fish trap. Spawning removal refers to the hours dedicated to removing fish during the spawn. A total of all aforementioned hours was totaled and listed. A cost associated with those hours was given at a rate of $20 per hour.

Temple Fork drainage **Species**	**Pass 1**	**Pass 2**	**Total fish removed**
BNT	1561	907	2551
BKT	358	151	566
BCT*	270	245	515
Spawning removals			
BNT	83		
BKT	57		
Total fish removed			3,117
Removal effort (hrs)	785		
Trap (hrs)	124		
Spawning removal effort (hrs)	23		
Total hours of effort	932		
Cost @ $20/hr	$18,640.00		

<u>Abundance of BNT in Temple Fork</u>

The stream reach with the highest abundance of BNT in Temple Fork was reach 5. Reaches 1 and 4 in Temple Fork also demonstrated very high densities. Figure 5 illustrated where BNT were most abundant and if future removal efforts were recommended, these hot spots may be a better place to put limited effort, time and money for removal of BNT. Additionally, most reaches in Temple Fork were difficult to shock due to woody vegetation and complex habitats. Reach 2 reflects this constraint as

more fish were captured on the second effort than the first effort (R Core Team 2013; Figure 5).

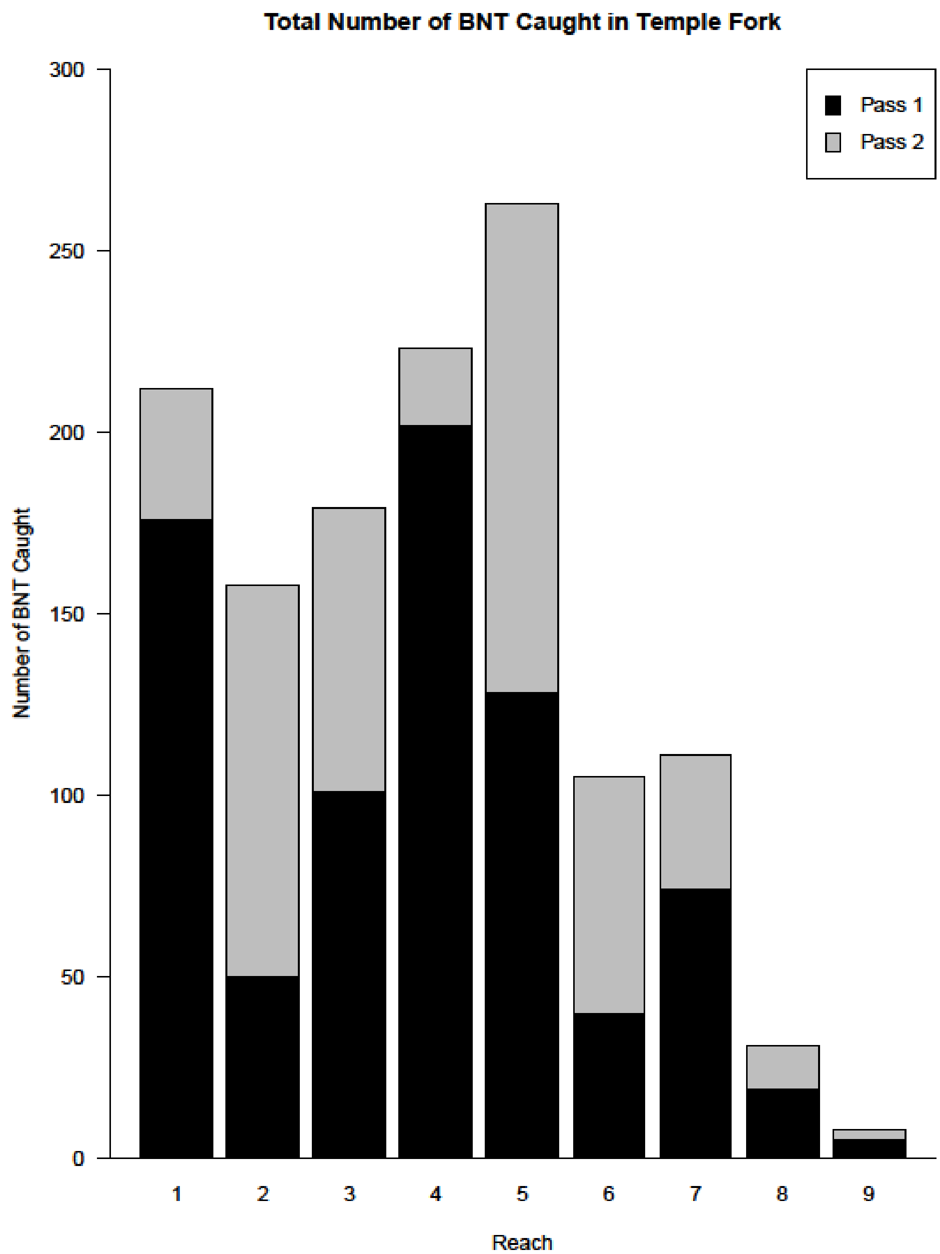

Figure 5. Total number of Brown Trout captured and removed in two electrofishing passes from nine reaches of Temple Fork, Utah during the period 21 August - 5 December 2019.

Abundance of BNT and BKT in Spawn Creek

Spawn Creek with its narrow widths, woody vegetation, and beaver dam complexes was difficult to electrofish. Reach 3 in Spawn Creek contained all of those habitats. Reach 3 displayed the highest densities of BNT. Reach 5 displayed high numbers and contained multiple beaver complexes and braided channels. Again, these may be reaches to focus future removal efforts if effort, time and money were limited for future removals. Our second pass yielded more fish than our first pass in reach 2 (Figure 6). We removed two BNT in reach 6 on the first pass. A very large beaver dam spans the entire riparian corridor and may be a fish barrier for BNT attempting to move upstream. We observed BKT in reach 5 downstream of this dam and many above this beaver dam in reach 6. BKT may have been stocked above this beaver dam (UDWR unpublished stocking report 1965). The location of this dam was in UTM 12T 453382 m E 4631985 m N in Google Earth. The dam was first documented in Spawn Creek in 1937. (UDWR 1965).

Brook Trout were only observed in reach 5 and 6 of Spawn Creek. Brook Trout dominated the beaver dams and pools. We observed a BKT density in reach 6 nine times that of reach 5. Again, these numbers may represent the difference of above and below the large beaver dam (Figure 7).

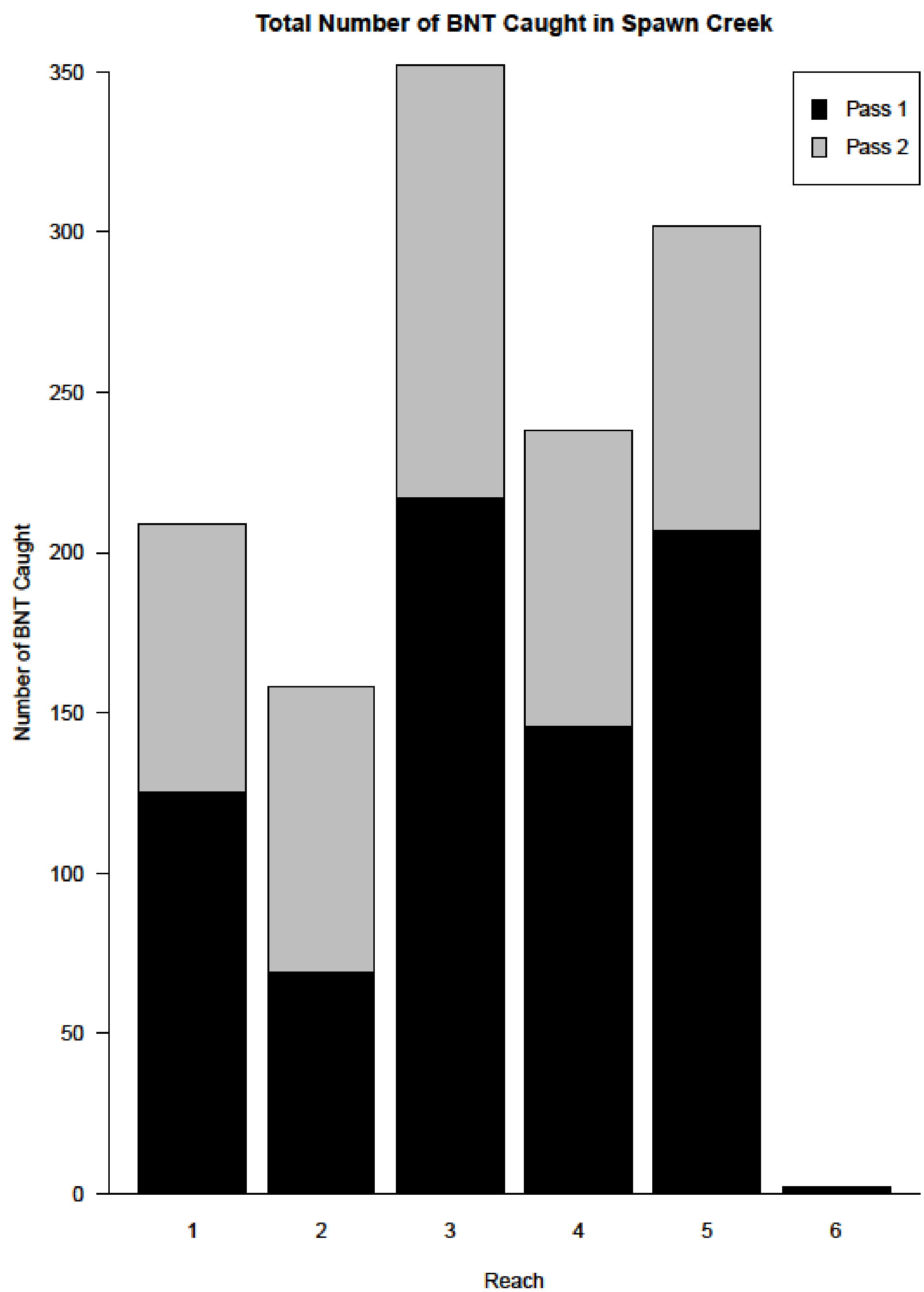

Figure 6. Total number of Brown Trout captured and removed in two electrofishing passes from six reaches of Spawn Creek tributary, Utah during the period 21 August - 5 December 2019. We captured brown trout in all six reaches of Spawn Creek.

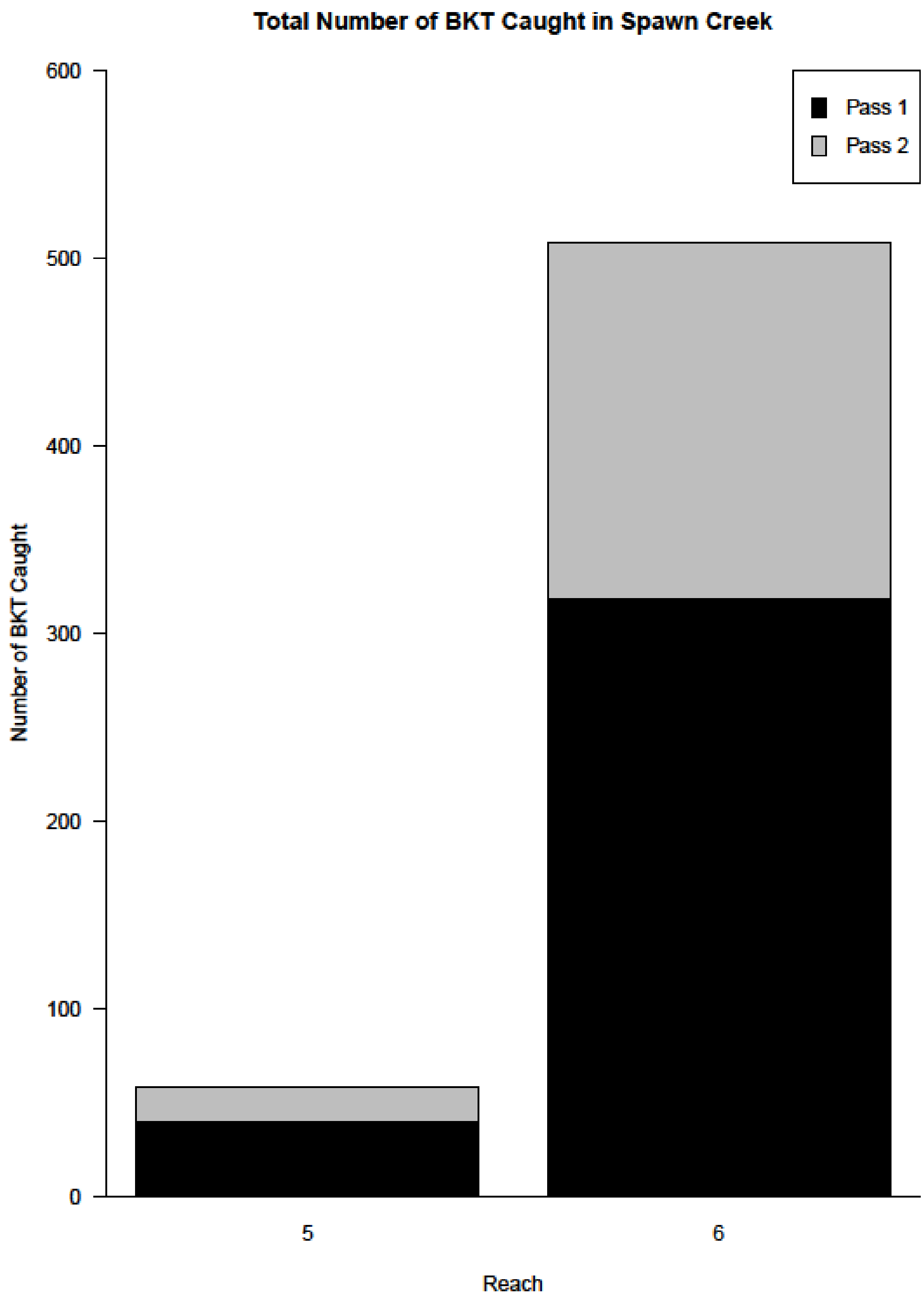

Figure 7. Total number of Brook Trout captured and removed in two electrofishing passes from two reaches of Spawn Creek tributary, Utah during the period 21 August - 5 December 2019. We captured brook trout in only reaches 5 and 6 of Spawn Creek.

BNT densities in Temple Fork

For the purpose of this study and in order to display the histograms appropriately, we created bins of twenty (20) mm length bins. For example, a BNT with a length of 77 mm was placed in bin 60 – 80 mm. Each fish within 60 – 80 mm was placed in the bin and a frequency (count) tabulated. In the nine reaches of Temple Fork, BNT in the bins of 40-60, 60-80, and 80-100 mm composed a large portion of the population. We used lengths up to 100 mm for YOY BNT based on research from Beard. His research documented YOY BNT were up to 101 mm during his study (Beard 2011). We also observed a significant pulse of fish from 40 to 100 mm in the histograms and made the break between age 0 and age 1 based on this observation. Forty three percent of BNT were YOY fish. We calculated this figure as:

$$\% = (Total\ of\ YOY\ BNT / Total\ of\ All\ Ages\ Caught)*100.$$

Reaches 1-6 demonstrated larger numbers of YOY BNT than any other group in each individual reach. The highest concentrations of BNT, reaches 2, 3, and 5 were also associated with the highest overall densities which may be correlated to higher densities of beaver ponds on the stream and provide YOY and winter refuge for fish. The top three reaches 7-9 decrease in overall BNT abundance and very few YOY fish (Figure 8).

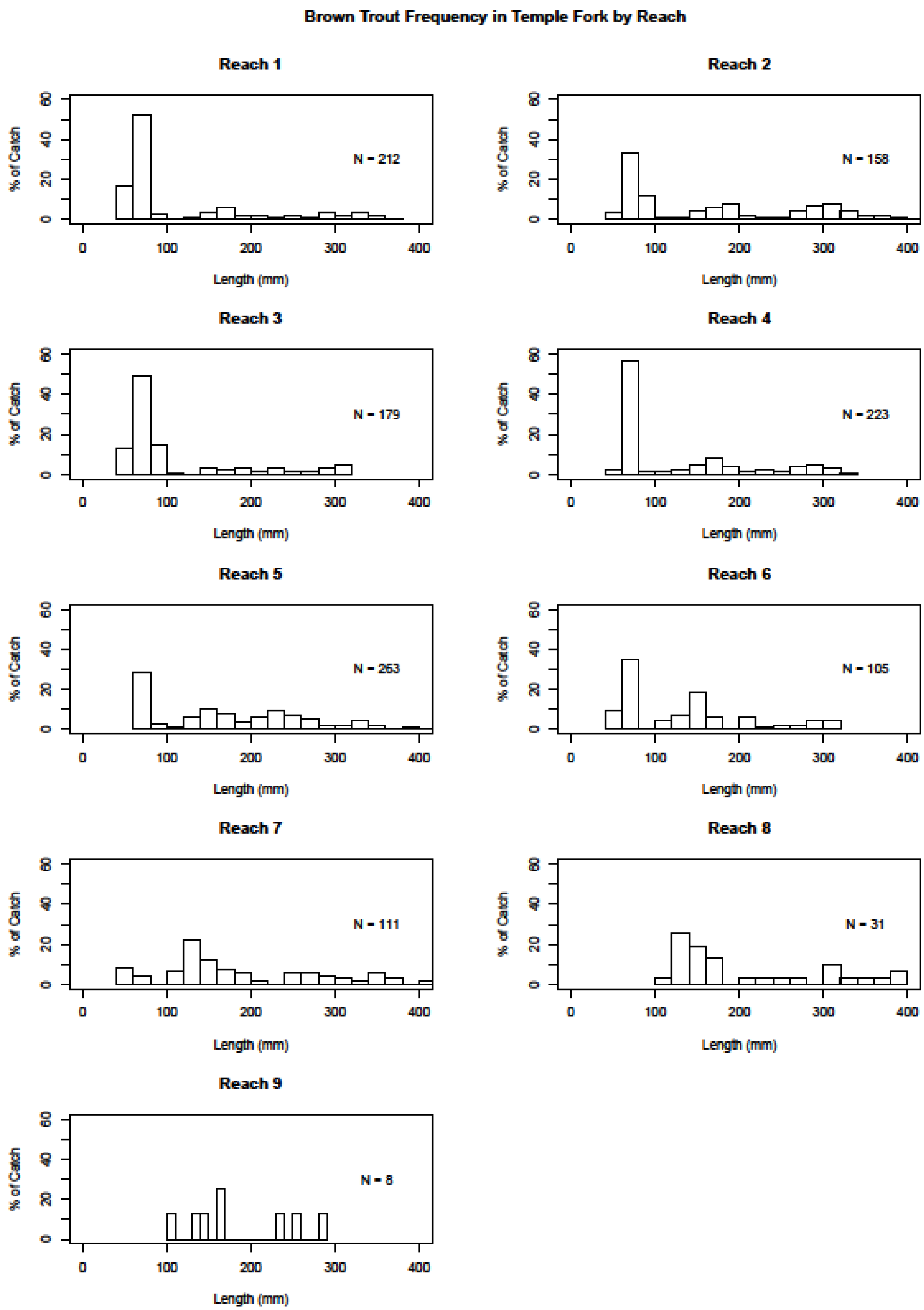

Figure 8. Length frequency (as percent) of Brown Trout captured and removed across two electrofishing passes in nine reaches of Temple Fork, Utah during the period 21 August - 5 December 2019. Length was measured as total length.

Densities of BNT in Spawn Creek

Spawn Creek demonstrated similar recruitment rates of BNT to Temple Fork. We observed high numbers of YOY BNT in reaches 1-3. Additionally, larger BNT were more prominent the further upstream we sampled. Specifically notice in figure 9 that fish numbers of 60-100 mm were highest in reaches 1-3 and constituted twenty three (23) percent, while reaches 3-5 illustrated higher densities of BNT larger than 100 mm and those above 200 mm which were sexually mature fish (Taube 2011). These larger BNT spawn higher in the drainage. Fry produced from those BNT drift in the flows until they find backwater areas for refuge created from beaver dams. As more beaver dams were built further downstream more of these fry may be recruited into the population in these lower reaches (Figure 9).

Densities of BKT in Spawn Creek

The size distribution of BKT in Spawn Creek was similar to BNT in Spawn Creek and Temple Fork. Both reaches 5 and 6 included a sizable number of YOY BKT, demonstrating recruitment was occurring. We sampled a fair number of BKT in reach 5 but possibly due to higher populations of BNT, reach 5 had fewer BKT. However, BKT numbers were exceedingly high in reach 6. We measured nearly 200 BKT from 120 – 160 mm in reach 6. We removed eighty nine (89) percent of all BKT captured from reach 6 (Figure 10).

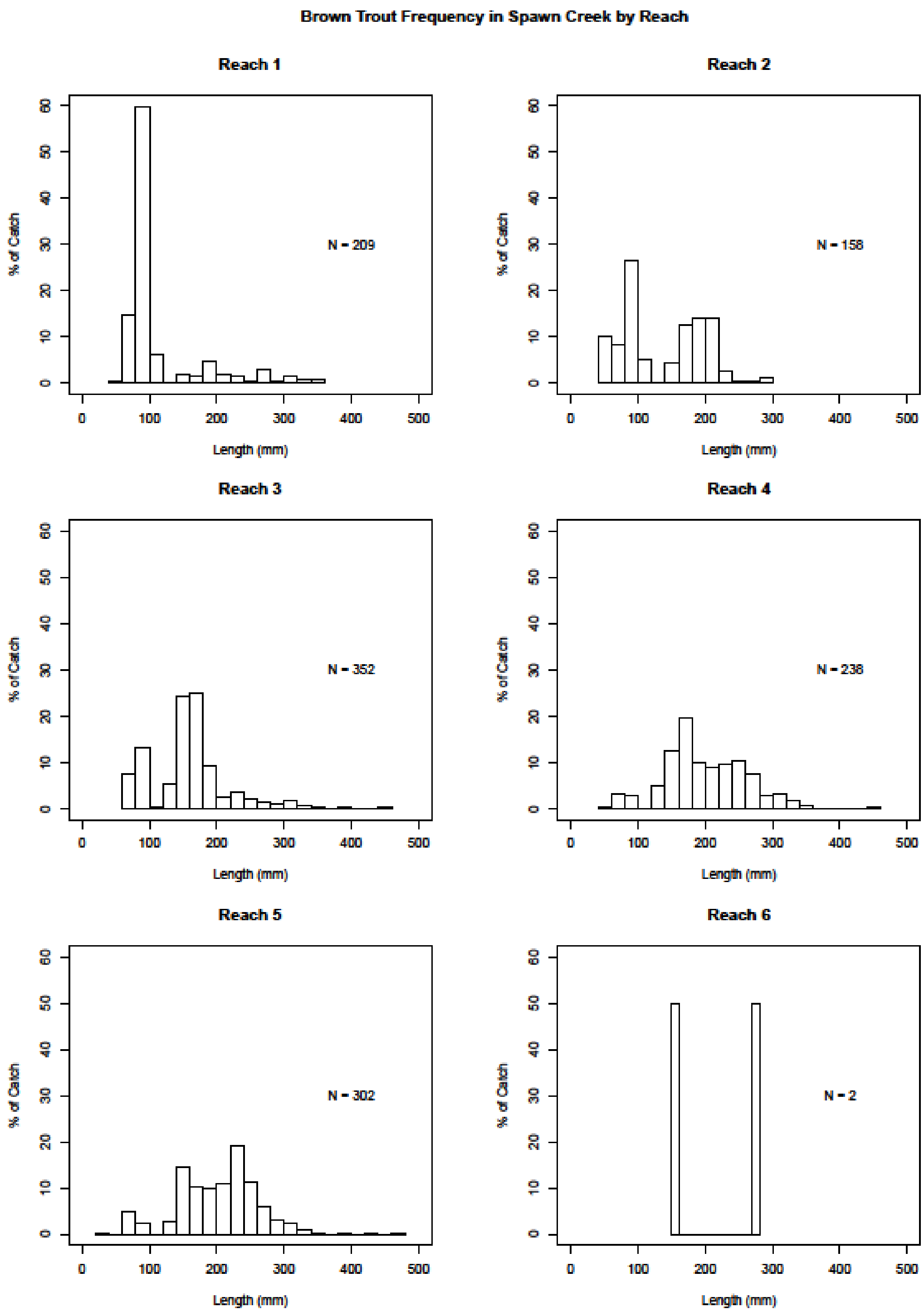

Figure 9. Length frequency (as percent) of Brown Trout captured and removed across two electrofishing passes in six reaches of Spawn Creek tributary, Utah during the period 21 August - 5 December 2019. Length was measured as total length.

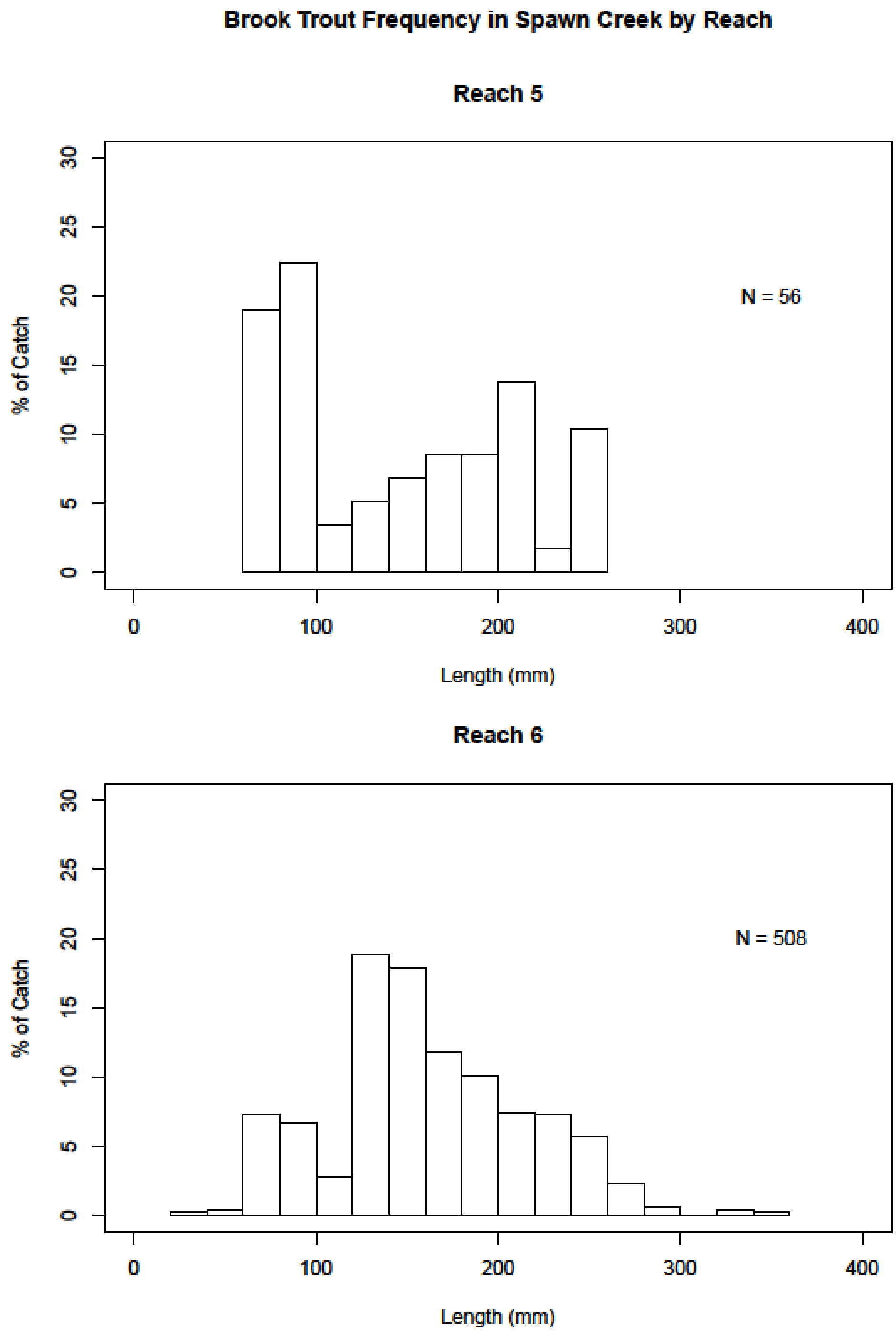

Figure 10. Length frequency (as percent) of Brook Trout captured and removed across two electrofishing passes in two reaches of Spawn Creek tributary, Utah during the period 21 August - 5 December 2019. Brook Trout length was measured as total length. We captured brook trout in only reaches 5 and 6 of Spawn Creek.

Spawning removal effort in Temple Fork and Spawn Creek

We collected 77 BNT and 57 BKT during two spawning removals on Temple Fork and Spawn Creek. We observed spawning BKT and BNT in reaches 4-6 on 8 November in Spawn Creek. The following day, 9 November, a small crew returned and removed as many spawning non-native fish as possible. We removed a total of 56 BNT and 57 BKT from reaches 4-6. We returned to Temple Fork on 14 November, for a removal effort. We started to electrofish reach 5. We encountered and removed spawning BNT on redds above several beaver ponds in the smaller gravels. We electrofished reaches 5 and 6 but BNT numbers and spawning activity were very low in reach 6. We removed 21 BNT during our effort (Table 4).

Table 4. Spawning removal efforts on Temple Fork and Spawn Creek. Numbers of BNT and BKT during each effort by stream and reach.

Spawning removal on Temple Fork and Spawn Creek				
Date	**Stream**	**Species**	**Reach**	**Number removed**
9-Nov	Spawn Creek	BNT	4-6	56
9-Nov	Spawn Creek	BKT	5-6	57
14-Nov	Temple Fork	BNT	5-6	21

Length and weight were collected on all fish and added to the total effort numbers per stream and reach, respectively. We summarized length frequency total for all trout collected in the two removal efforts, spawning removals, and the fish trap work (Figure 12). The histogram demonstrated BNT and BKT dominated these tributaries. BNT were the most dominant species in the drainage. The BCT numbers were

inaccurate because we only collected data on BCT previously captured and missing an adipose fin. BCT numbers were higher than represented (Figure 12).

Health condition from past 10 years

We observed very little fluctuation in K over all the years and age classes. We combined the streams together in these year classes to see if the mean condition factor K would differ. We compared by data collected in August against the previous years, and our condition factors were almost exactly the same as USU's data. Condition factors fluctuated from 0.97 to 1.05 in BCT and 0.98 to 1.06 in BNT from USU data. Our data was 1.03 to 1.09 in BCT and 0.98 to 0.99 in BNT. There was not a significant difference between all the data.

Fish trap

Evaluating the data collected at the fish trap, we did not observe a clear connection between migrating BNT from the Logan River and movements into and out of Temple Fork. In the lower reaches of Temple Fork, immigration from the Logan River by mature adult BNT was also possible. We installed the trap on 23 September, and at least once a day, we cleaned and checked the trap (Figure 11). During the next 11 weeks, we collected six BNT. Several times we encountered BNT at the trap but they spooked downstream as we approached to check the trap. At other times, fish were observed above and below the trap but no fish in the trap. We checked the pickets daily to ensure proper depth into the substrate of the stream. The trap did shift, and we did replace the first set of traps with a heavier and more robust version. Once the second

traps were installed, very little movement and shifting occurred. We observed no areas where fish could pass around or through the trap. We removed three BNT entering Temple Fork and three leaving Temple Fork. All fish were males from 294 mm to 355 mm in length. Two of the fish leaving and one entering were captured as we removed the trap on 5 December. Additionally, the two downstream moving fish had bite marks, presumably from a mink. Upon further investigation, we found where the mink entered above the trap and possibly stole fish from the trap. We suspected a mink ate several or more fish caught in the trap during evening hours after we checked the trap for the day and before the next day. This potentially diminished the total number of fish caught in the trap and skewed the data showing relatively low numbers of BNT trying to enter into Temple Fork to spawn.

Figure 11. Picture of the picket weir (fish trap). Installed and operated from 23 September to 5 December 2019.

Our removal efforts revealed greater distribution and densities of both BNT and BKT throughout the entire drainage than previously known (Figure 13). Larger populations of BNT were observed in reach 2 and 5 in Temple Fork. Both of these reaches contained several beaver dams which provided habitat for rearing YOY BNT and winter refuge for all age classes of fish. We observed a similar result in Spawn Creek reaches 3- 6 for BNT. BNT numbers were higher in reaches 3-5 where extensive beaver activity occurred. The large density of BKT was easily observed in reach 6. Reach 6 held the highest density of fish in the entire drainage.

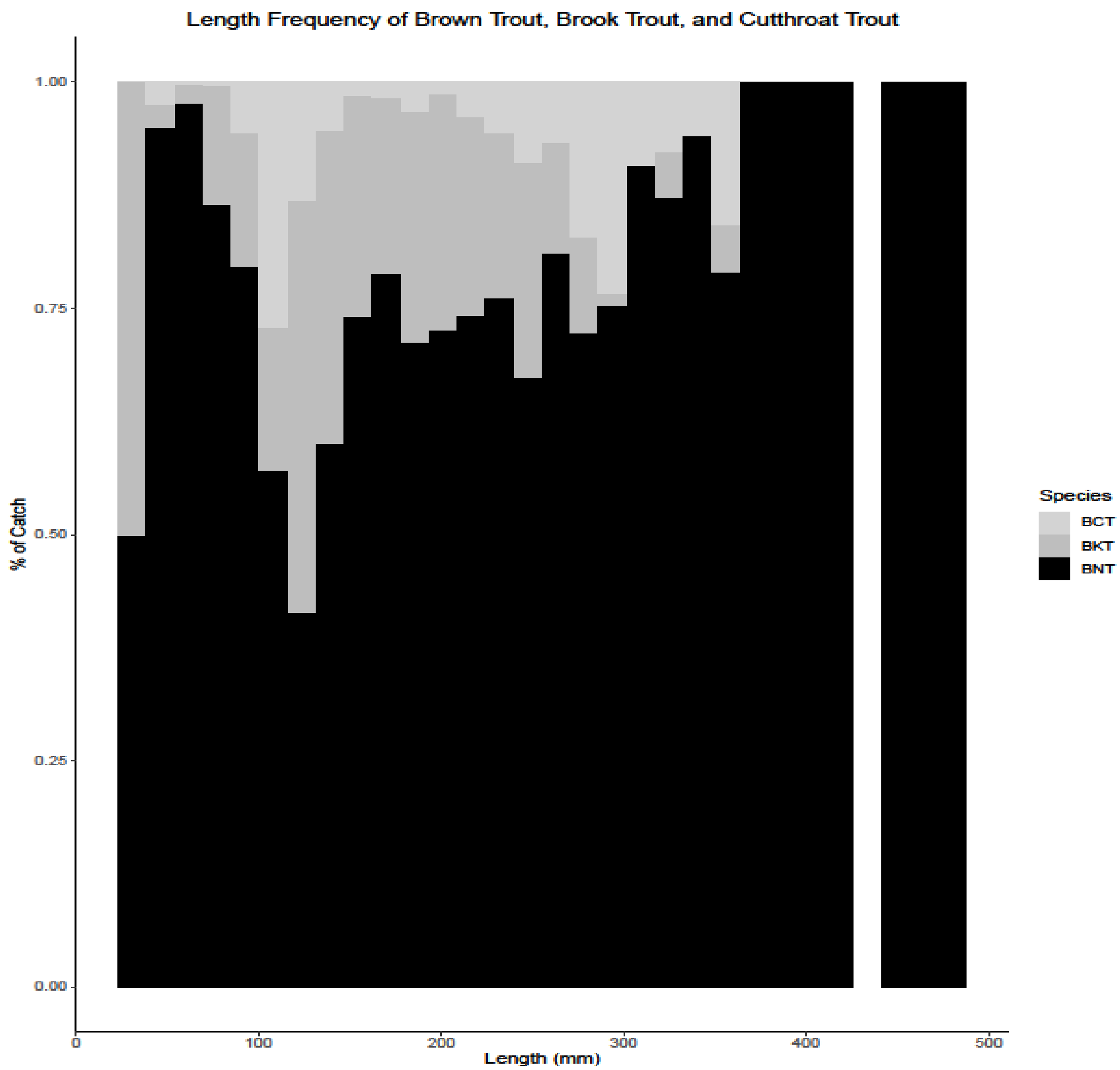

Figure 12. Length frequency (as count) of all trout (Brown Trout, Brook Trout and Bonneville Cutthroat Trout*) captured across two electrofishing passes in Temple Fork and Spawn Creek during the period 21 August – 5 December 2019. *Cutthroat Trout were released after data collection. This graph illustrates an additive population of trout with BNT constituting most of the biomass in Temple Fork drainage. Blank space between 400 and 500 mm represents zero fish of this length were collected in all sampling efforts.

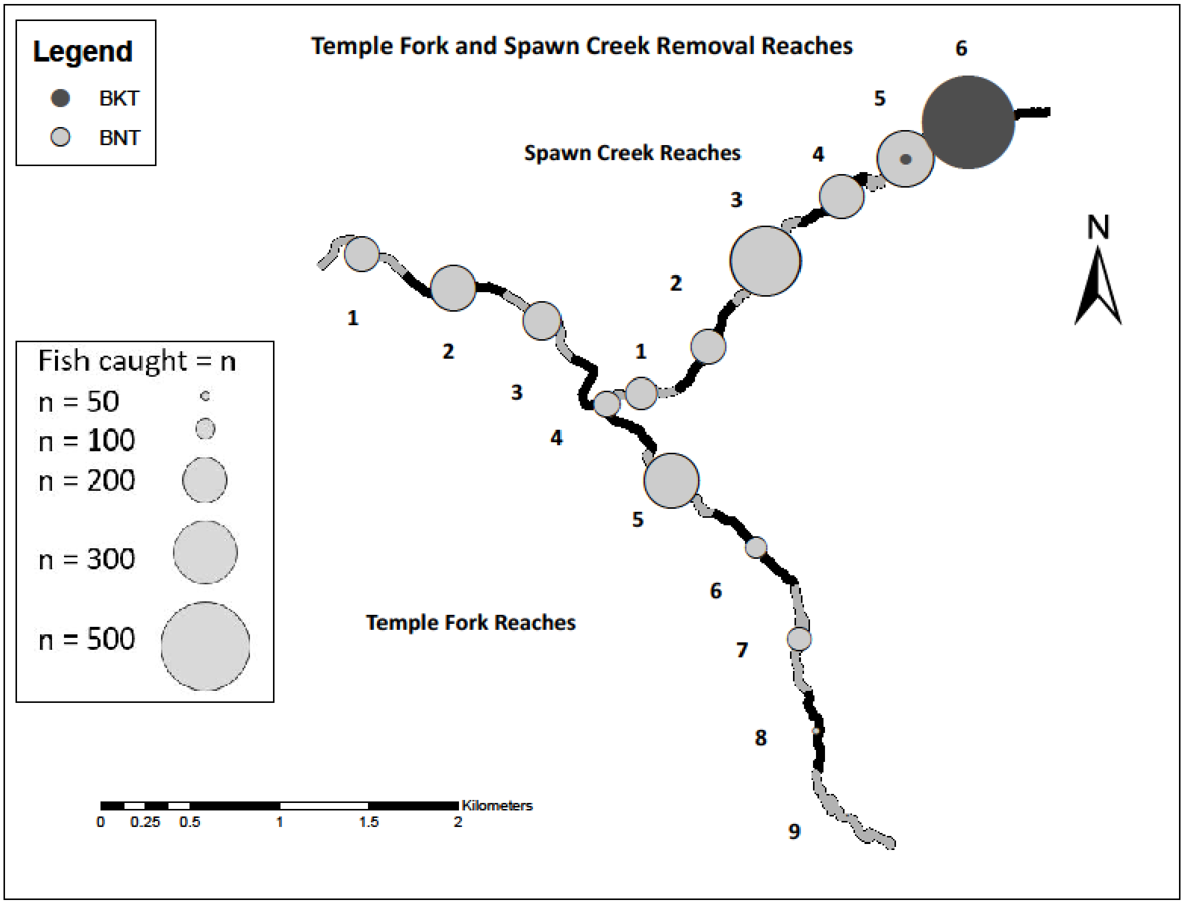

Figure 13. Densities of Brown Trout and Brook Trout within the Temple Fork drainage. Numbers of fish collected was based on two electrofishing passes in Temple Fork and Spawn Creek during the period 21 August – 5 December 2019.

BNT distribution in Temple Fork

In Temple Fork, we encountered BNT in all nine reaches of the stream. Total captured fish ranged from eight BNT in reach 9 to 266 BNT in reach 5 as the highest reach density. The lengths for BNT ranged from 41 mm to 470 mm. BNT were reproductively mature in this system at age 2+ and a mean length of 200 mm (Bridges 1863, Taube 2011; Figure 8). Based on this research, we collected 708 BNT of 200 mm

or greater from Temple Fork and Spawn Creek. BNT were collected in 8.9 km of Temple Fork and Spawn Creek. On average there were 79.5 adult BNT/km in these two streams.

We determined the uppermost limits of BNT distribution in Temple Fork within reach 9. Reach 9 started at 12 T 452886 m E 4629354 m N at a small riffle. We collected a total of eight fish between both removal passes, five on the first pass and three on the second pass. The collected BNT were from the starting point to 168 meters upstream to a beaver dam. The next 518 meters yielded only BCT. This gives a distinct terminal point of distribution of BNT. BCT were protected by further expansion of BNT at least for a few more years due to this removal. Further, in 5,005 meters of electrofishing, we collected 1,095 BNT in Temple Fork. Our abundance was 494 BNT per km.

Brown Trout numbers fluctuated over the past decade in Temple Fork. A sampling survey in 2014 indicated 125 BNT per km in Temple fork. This number increased to 310 per km in 2015 but dropped in a survey in 2018 to 162 per km. By comparison, BNT numbers from our removal efforts demonstrated 494 BNT per km in Temple Fork, three times the numbers from a year earlier. We cannot directly compare these numbers with each other because we sampled almost all of Temple Fork and the USU crew only sampled a 100 meter reference site; however, we can compare relative densities. We also sampled beaver ponds which did not occur in USU's reference reach. The density of BNT in 2019 was slightly higher than those in Spawn Creek (Table 4.). In comparison in August we estimated only 2,473 BNT in Temple Fork. Our current population estimate was over twice that of an estimate illustrating a definite increase over the past 47 years (Cerven 1973).

The BCT numbers were incomplete for the table. We collected data on BCT which had been previously tagged and the adipose fin removed. This was a small fraction of the population of BCT in Temple Fork and Spawn Creek. These tables were based on those small percentages of the BCT population.

Table 5. Estimate of Brown Trout and Bonneville Cutthroat Trout in Temple Fork. Length and weight data per species including condition factor. Numbers of fish collected was based on two electrofishing passes in Temple Fork during the period 21 August – 5 December 2019.

Temple Fork Two Pass Depletion Table

Species	Total Caught	Population Estimate	±	Fish/km	±
BNT	1095	2473	753	494	150
BCT	138	139	3	28	1

	Length (mm)				Weight (g)				Average Condition Factor
Species	Mean	Std	Min	Max	Mean	Std	Min	Max	
BNT	137.28	89.65	46	425	67.90	112.76	0.4	872	1.04
BCT	185.77	78.09	72	333	102.29	105.90	4	381	1.04

BNT and BKT distribution in Spawn Creek

Our evaluation of Spawn Creek was very similar to Temple Fork. We discovered BNT in all reaches and BKT in two reaches in Spawn Creek. The BNT densities varied from two BNT in reach 6 to a high of 342 BNT in reach 3. Their lengths varied from 31 mm to 480 mm. Again, BNT over 200 mm were likely sexually mature in this system, and with BNT throughout the system, spawning was likely in every reach except reach 6 where we captured only two BNT, both on the first pass. Additionally, we discovered another terminal point of distribution for BNT. Those two BNT were captured and

euthanized very close to the bottom of reach 6. We captured 1,143 BNT in Spawn Creek, slightly higher than Temple Fork but in less stream length. We sampled 4,650 meters of stream in Spawn Creek. The BNT abundance averaged 402 BNT per km. In 2014, BNT per km were at 41 and increased to 90 per kmin 2015. Spawn Creek was not sampled in 2018 but our numbers demonstrate a large increase in BNT to 402 per km; four and a half times than the sample in 2015.

We started capturing BKT in reach 5 and two thirds through reach 6. The lengths differed very little from the BNT. The smallest BKT measured 31 mm and largest was 350 mm. The highest density of BKT occurred in reach 6 at 453 fish in that reach. The highest number of fish collected in the entire drainage in one reach! As we captured BKT and BCT in reach 6, we observed 4-5 BKT per BCT caught. Since we were not capturing BCT unless they were clipped, we only have this as a mental note and not documented. The abundance of BKT was extremely high at 734 BKT per km. Petty collected and analyzed data on BKT and separated his trout into three groups: juveniles, small adults and large adults. Juveniles were 80 mm in total length or less. Small adults were from 80 mm to 120mm. Large adults were fish larger than 120 mm total length (Petty et al. 2005). We based the small adult and large adult BKT segregations on similar breaks in our histograms at 100 mm and 220 mm respectively. We collected 468 BKT above 100 mm in total length in 1.15 km of Spawn Creek. First, 468 BKT above 100 mm represented 82.7% of the population of 566 BKT sampled in this work. Second, it represented 406.9 adult BKT per km in Spawn Creek (Table 5).

Table 6. Estimate of Brown Trout, Brook Trout, and Bonneville Cutthroat Trout in Spawn Creek. Length and weight data per species including condition factor. Numbers of fish collected was based on two electrofishing passes in Spawn Creek during the period 21 August – 5 December 2019

Spawn Creek Two Pass Depletion Table

Species	Total Caught	Population Estimate	±	Fish/km	±
BNT	1143	1870	292	402	63
BCT	16	-1	3	0	1
BKT	509	619	56	734	66

	Length (mm)				Weight (g)				Average Condition Factor
Species	Mean	Std	Min	Max	Mean	Std	Min	Max	
BNT	167.80	71.09	41	480	72.84	94.90	0.2	967	0.97
BCT	273.00	18.38	260	286	201.50	14.85	191	212	1.00
BKT	158.31	54.85	31	350	57.78	60.79	2	514	1.18

Discussion

Combining both tributaries illustrates an impressive effort and removal of non-native fishes. Brown Trout numbers have increased in Temple Fork based on evidence found by USU during their annual stream surveys and now this study. As discussed earlier, in 2017 a USU stream survey crew found 50 BNT in the Temple Fork reference site. One year later in the same reference site, the crew found 350 BNT. Brown Trout and BCT numbers have fluctuated since 2001. BNT numbers have increased throughout the entire Logan River system. Cutthroat trout numbers have maintained their densities in some reaches and declined in others such as Temple Fork. These BNT were originally from stocking by UDWR in the past and may have increased due to predation of BNT on BCT and other species such as Mottled Sculpin within this system (Budy et al 2008; Wood 2008; Al-Chokhachy R. et al. 2016), interspecific competition (McHugh and Budy

2005), invasion of BNT further upstream, and established resident populations within tributaries such as Temple Fork and Spawn Creek (Wood 2008).

The stocking of BNT and BKT into the Logan River system, the State of Utah, and the United States occurred in the late 1800s and early 1900s (Maccrimmon and Marshall 1968). We obtained past documentation of BKT stocking from unpublished paperwork from UDWR in 1965 in Temple Fork. Thoreson documented BNT, RBT, and BKT were stocked in the Logan River and tributaries (Thoreson 1949). Brook Trout were stocked into Spawn Creek in 1964 and 1965. In 1964, the UDWR stocked 3,878 BKT and 1,000 were stocked in 1965 (Unpublished UDWR stocking records). The precise stocking location was not given for any of these stockings, only given Temple Fork, yet our removal efforts documented BKT in Spawn Creek and not in Temple Fork. A road followed Temple Fork and Spawn Creek until 2000 when USFS closed the road and re-contoured a new one from 2000 to 2002. Stocking previously occurred along this road following the streams.

We observed 58 BKT in reach 5 and 508 BKT in reach 6. We removed 302 BNT in reach 5 and concluded BKT recruitment was limited due to competition and predation by BNT (Fausch K. and White R., 1981, Meredith et al. 2014). There was less competition and predation by BNT in reach 6 based on only two individuals being caught in removal efforts. Predation by BNT on other species was highly documented and certainly posed a threat to BCT persistence in Temple Fork and Spawn Creek.

We hypothesized another reason for the increase in BNT was due to one or more years of successful spawning and egg incubation through the later fall and winter in Temple Fork. McHugh and Budy (2005) observed these high elevation tributaries were possibly unsuitable for those life stages from egg to sub adult age. Increasing adult numbers of BNT in Temple Fork may afford a greater increase of spawning activity and resulting eggs to YOY BNT. If temperatures were a single degree higher from 2 degrees C to 3 degrees C, this could allow for thousands of new BNT fry to enter into the system.

Our research documented 708 BNT within the Temple Fork drainage larger than 200 mm which were sexually mature BNT (Taube 2011). We concluded these resident fish were the primary reason for the increasing numbers of BNT and BKT within the Temple Fork drainage. We deemed that these high numbers of mature BNT may account for a high percentage of YOY BNT produced in Temple Fork. These high numbers were also linked to quality habitat (Budy et al 2012). Past research indicated age 2 female BNT, 200 mm to 226 mm, were 70-85% mature and carried viable eggs. Fecundity correlated with increasing length and weight of female BNT. Average age 2 fish carried 449 eggs. Age 3 BNT were 95% mature. Each year above age 3 was 100% mature. Age 5 BNT, 500+ mm in total length, averaged 2,027 eggs (Avery 1985). Additional research concluded BNT egg survival in Temple Fork was 36.67% and 51.33% in Spawn Creek in 2007-08 (Wood 2008). Survival of these eggs to fry and to age 1 differed from 40.4-61.0% in several streams and correlated tightly to the increase in discharge (Lobon Cerviá et al 2017). Each year more BNT were recruited into Temple

Fork, Spawn Creek and the Logan River. High numbers of sexually mature BNT were evident.

Previous research showed BCT rarely move > 500 mm within this system (Burrell et al. 2000; Mohn 2016). Small movements similar to this in BNT indicated that adult fish greater than 200 mm above reach 2 in Temple Fork and all of Spawn Creek were likely resident fish. The top of reach 2 was 932 meters from the intersection of Temple Fork and the Logan River (refer to figure 4 for reach location). Thus fish beyond reach 3 were highly likely to be resident. We documented to a small degree and attempted movement of BNT into Temple Fork by capturing 6 BNT in the fish trap. However, due to some apparent predation from mink, we were unsure of how many attempted to enter or leave Temple Fork.

A removal effort in August and September was determined to be most beneficial for multiple reasons. First, cutthroat trout eggs hatched post-spawn in both of the tributaries and if caught in electrofishing efforts, were separated based on size. If species was not distinguishable, these small young of year (YOY) fish were released. Second, BNT YOY were mostly between 60-90 mm and key markings were identifiable, compared to BCT which were under 50 mm. These YOY fish were extremely difficult to remove based on size, habitat used for cover, and how electricity was not as effective in immobilizing those (Budy et al 2008). Third, weather during both August and September was pleasant for the physical work required of the crews. This reduced exertion on crews and stress on cutthroat trout held in buckets for short time periods. Additionally, August and September have more consistent base flows allowing for more

consistent conditions to collect fish without high runoff flows or fall flash floods. We directed the removal efforts to remove BNT and decrease the numbers of BNT in the drainage.

The first removal effort, 21-23 August, required three days of electrofishing. The second removal effort, 24-25 September, required two days. Crews diligently scoured the water under the vegetation and in the pools and riffles. Based on past experience in other streams, we assumed about two hours per reach to accomplish the first removal effort and two days of work. However, most reaches required a minimum of three hours to finish.

This was a highly collaborative project, and the removal effort of this project involved securing help from USU, USFS, Cache Anglers Trout Unlimited chapter, USU students, UCFWRU, and UDWR personnel. The overall effort for August and September removal efforts, the spawning efforts, and the fish trap totaled 932 hours. We sampled 10.1 km of stream twice and removed a total of 3,117 BNT and BKT from the Temple Fork drainage. In comparison, the Right Hand Fork (RHF) project from 2009 to 2011 removed BNT from 5.6 km of Stream. They removed 4,826 BNT in 581 hours in 2009, 5,453 BNT in 757 hours in 2010 and 4,966 BNT in 720 hours in 2011. Our removal efforts averaged 3.3 fish per hour, while their research collected 8.3, 7.2 and 6.9 fish per hour respectively (Saunders 2014). The process of mechanically removing fish from a 100 m reach for population estimates was tiring and 10.1 km was daunting. This removal effort was extremely difficult due to the length of work days, stream

conditions, large quantities of fish collected and recorded, weight of equipment, distances travelled by foot, and dense riparian habitat conditions.

Standard procedures for population estimates required a closed system which prevented fish from moving in or out of the system. We broke the assumption of the population being a closed system. Fish within Temple Fork and Spawn Creek moved in or out during the sampling periods. Block nets were not placed in either stream. Our sampling efforts occurred over a total of five days with roughly a month of time in between for movements throughout the system. We knew the numbers collected were incorrect and by breaking these assumptions the numbers could only be used as a comparison.

Based on our findings and work, we supposed there were several mechanisms to reduce overall numbers of BNT and BKT within the Temple Fork drainage. First, mechanically removing invasive fish was possible with enough time and help. Second, increasing harvest of BNT and BKT can remove adult fish capable of spawning. Third, mandatory kill order (catch and kill) may be a possibility. Finally, mechanically salvaging BCT and then chemically treating the drainage could be a final effort to save BCT within this drainage from non-native invasion; however, this would be particularly challenging at this location because it was used by spawning BCT, moving in and out in spring/summer. Therefore a barrier would be challenging to manage. We provided evidence that mechanically removing BNT and BKT was very possible and Saunders indicated during a three year period (2009-2011) BNT age class structure shifted towards younger age classes 0 and 1 (Saunders 2014). Peterson stated the three

consecutive years of mechanical removal provided cutthroat trout a great opportunity to increase numbers after BKT removal. He suggested occasional removals of three years would be best with a few years in between instead of chemically treating the stream (Peterson D. et al 2004). We suspect if similar actions were taken over the same three year period, a similar shift would occur. Though this would be a very time consuming and laborious operation, this may provide the best outcome over time. The crews were very effective in covering most stream widths and depths with the Smith-Root electrofishing units. However, due to very thick riparian woody vegetation, deep pools, beaver ponds, or very wide channels, we knew our efforts did not collect every fish in each reach. In some instances and in very specific areas, two electrofishing units would have been beneficial to cover additional stream width (Hough-snee et al. 2013). Most of the beaver ponds we encountered did not logistically allow us to shock more than just the edges, leaving very deep portions untouched. There were several ponds where even with different electrofishing equipment we could not have sampled. There were instances where only the person electrofishing was able to be in the stream and the rest of the crew stayed behind or was out of the stream due to the vegetation or narrowness of the stream channel. If shocked fish were not caught by the first individual shocking, a percentage of those fish were lost. We knew despite our very best efforts to capture all non-native trout in these two streams, we missed fish. The work was very difficult and taxing on a person's body to carry the electrofishing unit for even a few hours, but add in the elevation, terrain, and vegetation, our crews did incredibly well. We selected individuals for carrying the units and those netting based

on previous knowledge of their skills using this equipment. This was an incredible experience but very difficult work (Bridges 1963, Peterson JT 2004, Saunders et al. 2014).

There were three different regulations which occur on the Logan River and its tributaries. UDWR has removed complications to their guidebooks over the past 5 years within the regulations for fishing and hunting. The fishing regulations on the Logan River were that a person could keep up to four trout or whitefish and use any legal tackle to do so from Card Canyon Bridge downstream to Cutler Reservoir. From Card Canyon Bridge to Red Banks the regulation was two fish and artificial flies and lures only. From Red Banks and above to the headwaters, a person was allowed two fish and any legal tackle could be used but only from the second Saturday in July to the end of the year. A change to the regulation to allow unlimited harvest of BNT or BKT and give an angler the opportunity to harvest additional BNT or BKT above those already allowed per reach and regulation on the Logan River. Anglers would still have to use flies and lures only in the middle reach but would be able to take home more fish as long as they were BNT or BKT. However, recent work by UDWR in creel surveys and population estimate work indicated rivers such as the Logan, Blacksmith Fork, Weber and Provo Rivers, have 95% or higher anglers which practiced catch and release with all fish caught regardless of species. Increasing limits for harvest would encourage a few anglers to take home more fish but the overall affect may not reduce BNT numbers as desired. In the most recent Logan River creel survey, 7% of all anglers fished specifically for BNT;

however, that said, continued education and outreach could eventually change this attitude.

The UDWR currently has several mandatory kill (catch and kill) waters throughout the State of Utah. These have typically been for illegally introduced species such as Burbot, Walleye, or Northern Pike. However, on the Logan River, the UDWR has stocked BNT, BKT and RBT for over a century. Anglers have relied on stocking reports for angling opportunities with higher catch rates. Enacting a catch and kill regulation for BNT and BKT could be politically difficult for the UDWR. Internally, biologists and managers have to agree on whether such an action would be useful in obtaining a desired outcome of reducing non-native fish numbers in the Logan River. If there were an agreement then coordinators and the Chief would have to agree as well. This information would be taken to the Regional Advisory Council (RAC) and Wildlife Board process. This was a public forum where groups and individuals could share their insights and feelings. We suspect this catch and kill action would not pass.

Bonneville Cutthroat Trout have numerous encountered threats from predation of eggs, fry and juvenile fish from BNT and BKT (Jensen et al. 2008; McIntosh et al 2011), invasion from past stocking events from UDWR (Lowe et al. 2000; McHugh and Budy 2005; Budy et al 2008; Wood 2008), competition (McIntosh et al 2011; Mohn 2016), small harvest rates from anglers wanting to catch and release all fish caught, riparian grazing and trampling effects on redds (Gregory and Gamett 2009), and climate change (Wenger et al. 2011). Mechanically removing non-native fishes was very laborious and time intensive. Potentially removing age 2 and greater age classes from these efforts

removed sexually mature fish from the population and changed the age demographics within the BNT and BKT population. We suspect targeting non-native trout during the spawning season (October through December) would further reduce age 2 plus fish. Success has been demonstrated using one pass electrofishing removal efforts and changing the age structure of non-native BNT (McIntosh et al 2011). Redds found during these spawning removal efforts could also be trampled to reduce a pulse of age 0 fish the following year (Kelly 1993).

Additionally, a slight increase in temperatures of one or two degrees Celsius may allow for better egg development and hatching, fry survival and better overall YOY BNT survival (McHugh and Budy 2005). Protecting tributaries on the Logan River from further movements of BNT into them may be required. A large barrier could prevent BNT expansion; however, based on only BNT captured in the weir, installation of such a barrier seems unnecessary and expensive. If further operation of the weir proved more BNT enter into the system then a discussion between USU, UDWR, USFS, TU, UCFWRU, and USGS would need to happen. Currently though, a schedule to mechanically remove non-native trout from Temple Fork and Spawn Creek may be the most sensible solution to non-native expansion, perhaps this effort could occur every other or every third year based on our observations herein and the history.

Temple Fork and Spawn Creek were tremendous spawning areas due to high quality connected habitats, cold and clear water, and consistent water flow and temperatures. We suggest that efforts be taken to maintain this dense population of BCT by continuing removal efforts as budgets and time allow between all agencies

involved, operating the fish trap through the fall again to capture better movement patterns and numbers of BNT trying to move into the lower reaches of Temple Fork, offering additional harvesting opportunities for those anglers who wish to take home fish, and considering a permanent barrier to prevent non-native trout from re-entering this tributary. We should also continue to work with the public through outreach and education, as angler values have changed greatly over the last decade.

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pages.

Appendix A

Table 7. Estimated costs for the overall project.

Budget		
Actions	Description	Amount
Personnel time for weir	Operate picket weir from September to December	6,000.00
Materials and supplies	PIT tags and supplies for removal efforts	6,000.00
Motorpool	Miles for truck	3,000.00
Other	Permits etc.	2,000.00
Total		17,000.00

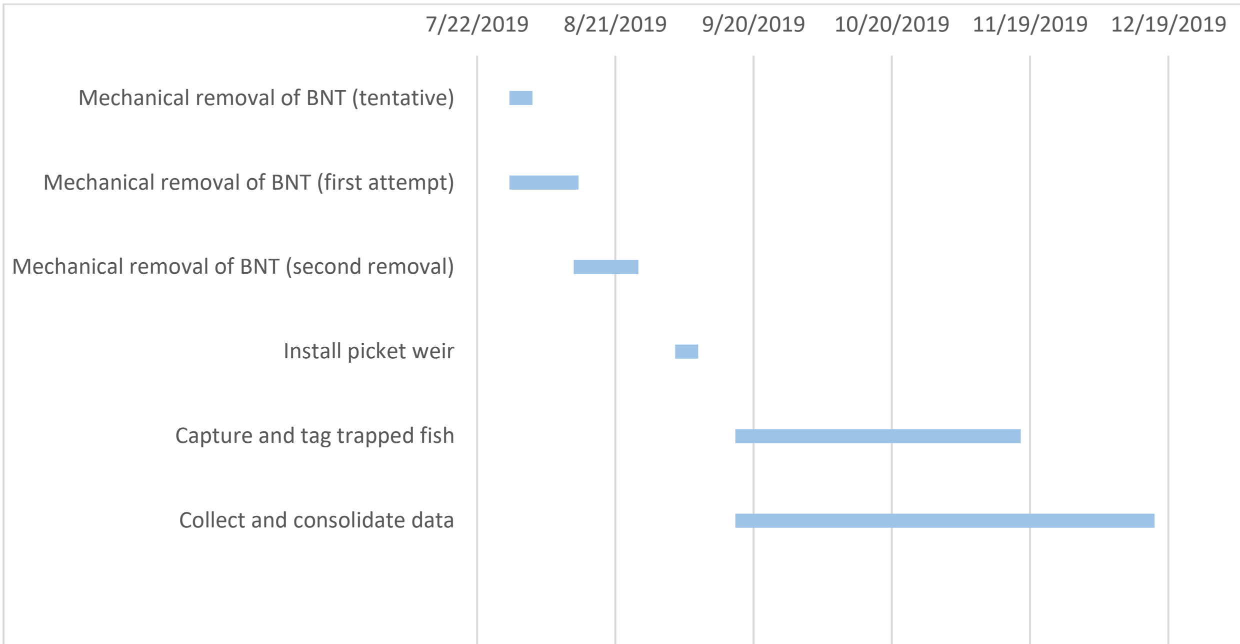
Table 8. Estimated amounts of money and contributors for the project.

Funding Sources		
	In-kind	Cash
Cache Anglers	2,000.00	1,000.00
USFS	2,000.00	2,000.00
Blue Ribbon		7,500.00
Utah Cutthroat Slam		2,500.00
Total Contributions	4,000.00	13,000.00
Total		17,000.00

Table 9. Actual expenses on the overall project.

Actual Expenses	
Personnel time	1,300.00
Materials and Supplies	2,500.00
Motorpool	1,500.00
Other	0
Total	5,300.00

Appendix B



7/22/2019
8/21/2019
9/20/2019
10/20/2019
11/19/2019
12/19/2019
Mechanical removal of BNT (tentative)
Mechanical removal of BNT (first attempt)
Mechanical removal of BNT (second removal)
Install picket weir
Capture and tag trapped fish
Collect and consolidate data

Appendix C

Photo 1. Pictures clockwise from top left. Electrofishing crew removing non-native fish. Crew electrofishing a beaver pond. Technician Jaren Hutchinson assembling picket weir. Picket weir functioning. Adding pickets to the weir. All construction pieces in place for assembly.

Photo 2. Pictures clockwise from top left. Bonneville Cutthroat Trout. Brook Trout. Cooler of Brown Trout removed from Temple Fork. Bucket of Brown Trout.