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Relating Habitat Use to Survival of Oncorhynchus in Rock Creek and the Clark Fork River

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RELATING HABITAT USE TO SURVIVAL OF ONCORHYNCHUS IN ROCK CREEK AND THE CLARK FORK RIVER

By

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ABSTRACT

Westslope Cutthroat Trout *Oncorhynchus clarkii lewisi* (WCT) is a native trout species of conservation concern in Montana. Both migratory and resident life histories can be found in cutthroat from the same natal stream. Habitat degradation and hybridization with rainbow trout *O. mykiss* (RBT) have resulted in few genetically pure, migratory WCT populations persisting in large river systems. These WCT conservation populations are occurring more and more as isolated, resident populations in headwater streams. Rock Creek in Western MT has retained a unique population of migratory, non-hybridized WCT, and is of special conservation and ecological interest. As we work to protect WCT and migratory life histories, we need to better understand how these fish use habitats and how that habitat use may relate to subsequent survival. From 2018 to 2021, 80 of these WCT, along with 81 hybrids and 29 RBT had radio telemetry tags implanted to be tracked primarily for spawning migrations and habitat use. I used locations and mortality indicators from radio telemetry data collected over the course of the three-year study to examine how survival differed between fish with varied genetic ancestry and then examined whether there was a relationship between survival and habitat use. There was no significant difference in annual survival between different ancestries of *Oncorhynchus spp*. I combined all 190 fish in the study to examine the association between survival and habitat use. Fish spending the summer (June, July, and August) in Rock Creek showed much higher survival rates than those spending the summer in the Clark Fork River. I found major differences in the habitats in question, with substantially higher temperatures in the Clark Fork River versus Rock Creek, but are also correlated with lower flow and higher contaminant levels. Results of this study build a better understanding of how survival relates to habitat use and can be useful to help protect and prioritize habitats.

ACKNOWLEDGEMENTS

I would like to start by acknowledging that the study area of Rock Creek in the aboriginal lands of the Séliš (Salish) and Ql’ispé (Kalispel) people whose name for Rock Creek is Np’nétk^{w} (Logs in the Water). They ceded these lands to the United States in the 1885 Hellgate Treaty but reserved their right to continue to hunt, fish, and gather plants here.

I would like to extend my gratitude to all those that helped in the process of making this project possible. My faculty mentor Lisa Eby was extremely helpful the last couple years in making this project what it is today. Lisa always challenged me to be my best and to think critically throughout this process. I would also like to thank UM graduate student Troy Smith who had a large role in developing the questions of this study. This project would not have been possible without Troy’s expertise in the R software.

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INTRODUCTION

Anthropogenic activities such as fish stocking and introductions, as well as habitat degradation and fragmentation have created significant loss of North American fish species such as salmonids (Jelks et al., 2008; Krueger & May, 1991; McClure et al., 2008; Reid et al., 2019). Anadromous salmonid species have been heavily impacted by dams and resulting habitat loss, resulting in loss of genetic diversity, population distribution, and overall habitat availability (McClure et al., 2008). Westslope cutthroat trout (*Oncorhynchus clarkii lewisi*, WCT), an inland trout species native to the Northwest United States and Southeast Canada, have current distributions that are only a small portion of historic range (Shepard et al. 2005). Given the dwindling status of native species, such as WCT, the importance of conservation efforts continues to grow (Williams et al., 2011).

Partial migratory life history is a trait that WCT populations exhibit across their range (McIntyre and Rieman, 1995). Partial migration is simply the phenomena where some individuals in a population migrate and some do not (Chapman et al., 2012). WCT display partial migration during spawning season. These fish have three life history forms: adfluvial, fluvial, or resident (WDFW, 2022). Adfluvial fish spawn in tributaries, but spend other times of the year in lakes. Fluvial fish migrate from rivers and spawn in tributaries. Resident fish spend their entire life where they spawn, never migrating to other waterbodies. Variable life history forms are important for population stability, promoting population connectivity, genetic diversity, and overall population persistence and resiliency (Heckel et al., 2020).

The Montana Natural Heritage Program considers WCT to be a “species of concern” in the state. WCT populations have seen severe declines in their historical distribution due to anthropogenic effects such as dams (Schmetterling, 2003), timber harvest (Hicks et al., 1991), livestock grazing (Peterson et al., 2010), and increased water temperature (Dobos et al., 2016). A key threat to WCT populations is hybridization with non-native rainbow trout (*O. mykiss*; RBT) due to spawning timing and habitat overlap (Muhlfeld et al., 2009; Yau & Taylor, 2013). As a result of habitat degradation and hybridization with RBT, non-hybridized, migratory WCT are becoming more uncommon in large river systems (Muhlfeld et al., 2009; Yau & Taylor, 2013). Shephard et al. (2005) estimates that non-hybridized WCT only exist in roughly 10% of their historic range, much of which is made up of resident populations.

As we work to protect WCT and migratory life histories, we need to better understand how these fish use habitats and how that habitat use may relate to subsequent survival. *Oncorhynchus spp.* require very cool stream temperatures. RBT and WCT show optimal growth rates between 13 – 14°C and upper incipient lethal temperatures around 24°C and 20°C, respectively (Bear et al., 2007). 18°C is the temperature where Bear et al. (2007) found WCT survival significantly decreases, and is the warmest temperature where WCT were observed in another MT study (Heinle et al., 2021). Several studies have highlighted the importance of high discharge and pool depth for habitat availability and overall survival in *Oncorhynchus spp.* (Berger & Gresswell, 2009; Sheldon & Richardson, 2022). Summer rearing habitat for adult WCT in the Coeur d'Alene River in Idaho was described as either pool or run habitat with a depth of at least 1 meter, but with a preference of depths > 2 meters (Groen et al., 2008). For coastal cutthroat trout (*Oncorhynchus clarkii clarkii*), researchers found low survival and poor habitat conditions during low flows in the late summer and early fall periods (Berger & Gresswell, 2009).

We examined survival of the migratory life history of *Oncorhynchus spp* in Rock Creek in Western MT, as it has retained a unique population of migratory, non-hybridized WCT, and is of special conservation and ecological interest. To model survival rates of *Oncorhynchus spp.* in

Rock Creek and the nearby Clark Fork River, we used radio telemetry to monitor habitat use and mortality events of WCT, RBT, and hybrids of these species. The study was focused on differences in habitat between the Clark Fork R. and Rock Creek and how that was related to seasonal survival. Survival was modeled for two seasons: summer, defined as June, July, and August; and winter, which was defined as November through March. Each fish was assigned a summer or winter "zone," which were assigned using the mean river kilometer the fish was located at during the given season. For these assignments, locations used for summer zone were from April through October, and for winter zone, observations used to make assignments were from November through March. Within the analysis of summer survival, stream temperature and discharge data were used to compare habitat conditions. The first question of the study was (1) did survival differ between the ancestries of fish in the study (WCT, RB, and hybrids)? If all fish in the study, regardless of ancestry, had similar survival, we could combine all of them into a single dataset to analyze effects of habitat-related seasonal survival. The second question was (2) were there differences in seasonal survival associated with seasonal habitat use? If so, were they broadly associated with flow and temperature?

STUDY AREA

Rock Creek is a 5^{th} order river system located east of Missoula, MT, USA (Figure 1). The mainstem of the river flows northward, starting at the confluence of the West Fork and Middle Fork of Rock Creek and flowing 83 km to its connection with the Clark Fork River, near Clinton. The Rock Creek watershed encompasses 1,725 km^2 and consists of confined valley channels and canyons. The upper portion of the Rock Creek drainage is largely private land and is managed for livestock grazing, the middle portion is mainly owned by the Forest Service, and the lower portion is mainly private, consisting of residential subdivisions (MFWP, 2019).

Rock Creek is one of the twelve blue ribbon trout streams in Montana (MFWP, 2019) and is one of the most popular fisheries in the state, ranked 10th in the state for angling pressure in 2017 (Liermann, 2022). This is largely due to high proportions of public lands and access and high densities of fish (MFWP, 2019). Historically, native WCT and bull trout (*Salvelinus confluentus*) were the primary inhabitants of the fishery. Today, Rock Creek is still managed as a stronghold for these two native species, but now also possesses brown trout (*Salmo trutta*), brook trout (*Salvelinus fontinalis*), and RBT. Brown trout make up a large portion of the recreational fishery and are a reason for Rock Creek's popularity (Liermann, 2022). Because Rock Creek maintains populations of migratory, non-hybridized WCT, RBT, and hybrids of the two, it is a stream of high ecological and conservation interest.

The study area is comprised of the entire mainstem of Rock Creek and the part of the Clark Fork River that tagged fish in the study utilized for summer or winter habitat. The area is divided into three sections (Figure 1). The sections are Upper Rock Creek, a more unconfined valley setting; Lower Rock Creek, a more confined canyon; and the Clark Fork River. Each section is defined by a specific river kilometer, and with these, we divided fish into sections to analyze survival in different habitats.

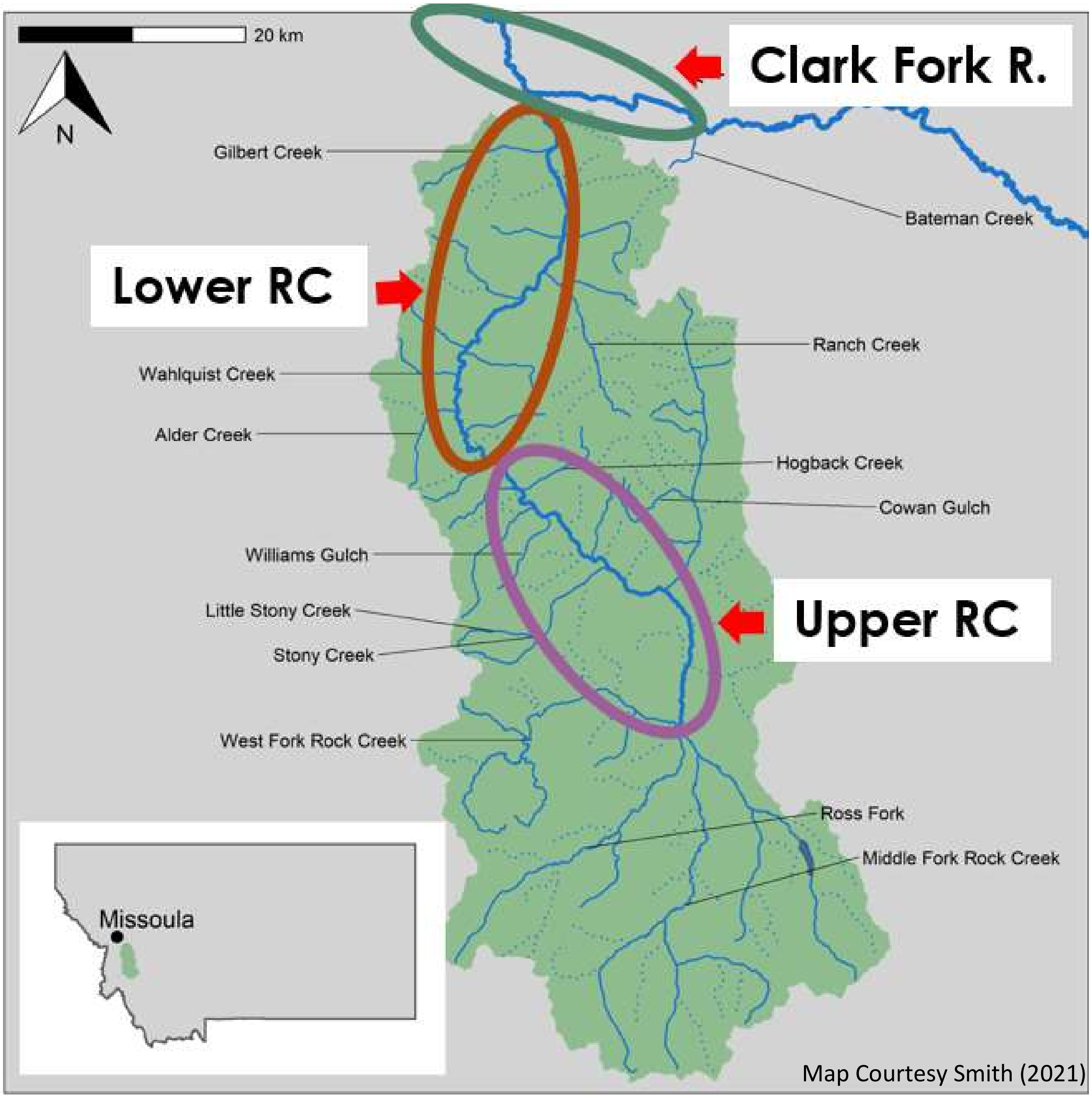

Figure 1: Map of the Rock Creek drainage. The approximate divisions of the study area include Clark Fork R. (shown in green), Lower Rock Cr. (orange), and Upper Rock Cr. (purple).

METHODS

Tagging and Relocations

Between April, 2018, and March, 2021, Montana Fish, Wildlife and Parks (MFWP) implanted a total of 190 fish with radio telemetry tags primarily to track spawning migrations and habitat use in and around the Rock Creek area. Of these fish, 80 were WCT, 81 were hybrids, and 29 were RBT. Fish that were tagged were greater than 330 mm total length as these fish were likely sexually mature. Fish were tagged throughout the mainstem of Rock Creek, as well as in the Clark Fork below the Rock Creek confluence. Tagging events occurred in both the spring and fall between 2018 and 2020, with only a spring tagging event in 2021. Though tagging location does not necessarily mean that is where fish would be in the summer or winter, it is worth noting that 19 fish were tagged in the Clark Fork, 113 tagged in Lower Rock Creek, and 58 tagged in Upper Rock Creek. The tags placed in the fish were equipped with mortality sensors. When a fish died and the tag was relocated, the code would indicate that the fish was dead.

MFWP and UM researchers drove the road that parallels the mainstem of Rock Cr. and the Clark Fork R. to relocate tagged fish. During spawning season, when fish would move into smaller tributaries without a nearby road to spawn, researchers walked along the stream to relocate the fish. During the spawning season (May 1st – July 15th), relocation surveys were typically completed every-other-day to determine spawning location and timing in tributaries. In the spring months prior to spawning season (March and April), summer months post-spawn (July – August), and fall months (September – November), relocations were usually made once or twice a week to gather information on habitat use and survival throughout the year.

Estimating Survival

To estimate survival, we used a Cox proportional hazards model (**Eq. 1**) (Cox, 1972; Pollock et al., 1989) with the survival package in R (Therneau & Grambsch, 2000) to assess the relative influence of RBT ancestry (Question 1) and seasonal habitat use (Question 2). Ancestry-based and seasonal survival curves were derived from the Cox models using the rms package in R (Harrell Jr., 2021).

Eq 1. $h(t|z) = h_0(t)\exp(\beta_0)$

Where $h(t|z)$ is the hazard for an individual at time t, $h_0(t)$ is the baseline hazard, and β_0 is the coefficient of the variables.

The Cox proportional hazards model is a known-fate model, meaning it takes into account the end fate of every fish in the dataset. When a mortality code was transmitted, it was assumed that the fish had died and would be confirmed either through tag recovery or user judgement. Fish that were never relocated again were censored out of the model, meaning that their survival up to the latest date of relocation would be accounted for in the model, but their fate was ultimately unknown. In the model, fish either died, were censored out, or survived until their tag failed.

Temperature and Discharge Data

To analyze the effects of different habitats on survival, summer stream temperature and discharge data were gathered as potential explanatory variables. Temperature data came from MFWP. Every summer of the study, five total temperature loggers were placed into the Clark Fork and Rock Creek. Two loggers were placed into the Clark Fork above the Rock Creek confluence, two placed in the Upper Rock Creek study section, and one in the Lower Rock Creek section. A weekly mean temperature was calculated for every week between July 1 and

September 1 which is typically the warmest time of year. Weekly means were chosen to show general trends and differences between habitats. Discharge data was gathered from the U.S. Geological Survey (USGS, 2021). Three USGS stations were used; Rock Creek near Clinton, MT (USGS station 12334510), Clark Fork at Turah Bridge nr Bonner, MT (USGS station 12334550), and Clark Fork near Drummond, MT (USGS station 12331800). The Rock Creek station is located close to the confluence with the Clark Fork, the Turah station is located downstream of the Clark Fork confluence with Rock Creek, and Drummond is above the confluence. A mean monthly discharge was calculated for each of the summer months (June – August) for each year in the study. For comparison, a monthly mean for June – August using data from the last 25 years (1997 – 2021) was also calculated. Discharge data was analyzed by comparing months in the study to the 25-year average to examine if the years of the study were associated with low flow outliers which may have resulted in differences in survival.

RESULTS

Survival of Oncorhynchus spp. among Ancestry

I determined whether there was a difference in annual survival rates between WCT, RBT, and hybrids (Figure 2). I combined data across years and used the first tagging event of the study (April of 2018) as the start of the cumulative survival probability. WCT had an annual survival rate of 25% (95% CI: 16 – 38%), RBT ('RB' in the figure's legend) had an annual survival rate of 31% (95% CI: 14 – 72%), and hybrids had a rate of 28% (95% CI: 16 – 48%). In all cases, the largest decrease in survival was between June and September. Given that all the survival rates were similar, with overlapping confidence intervals, I combined all tagged fish into a single dataset to analyze effects of habitat and seasonal survival.

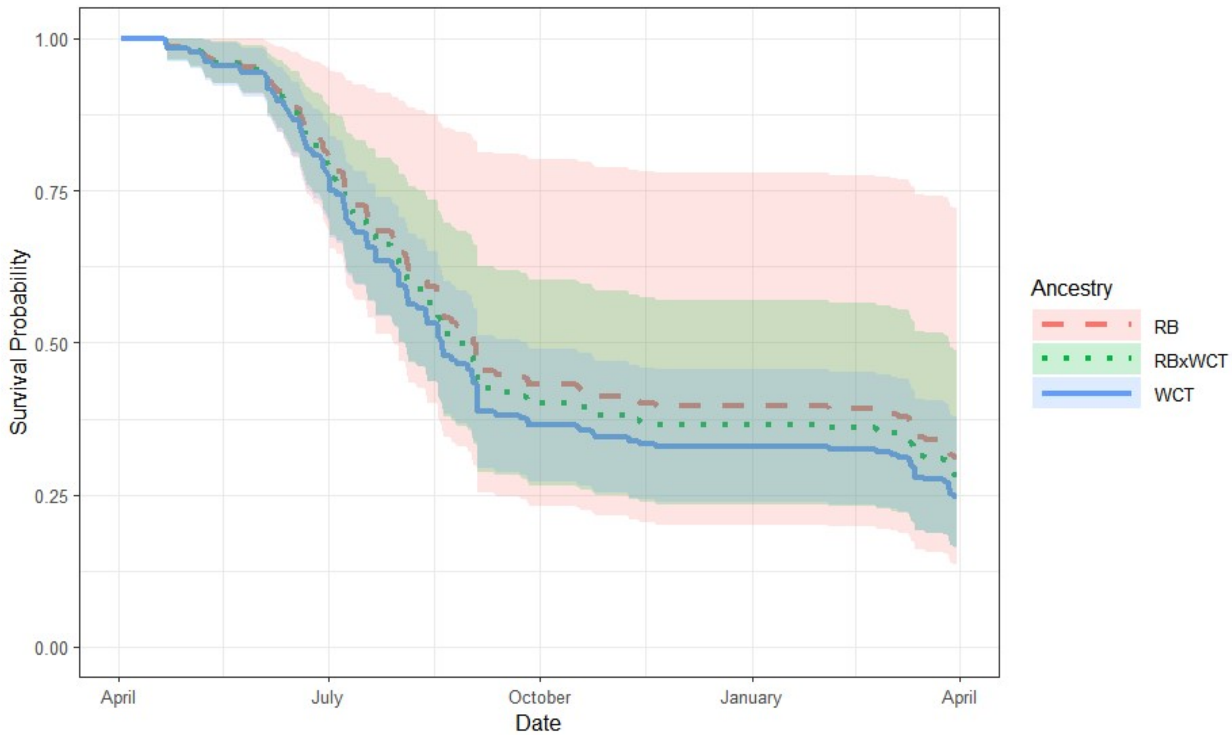

Figure 2: Estimated cumulative annual survival probabilities (ranging from 0 to 1) and 95% confidence intervals of westslope cutthroat trout (solid blue line), rainbow trout (dashed red line), and hybrids (dotted green line) from April 1st through March 31st derived from the Cox Proportional Hazards model. The survival probability represents the probability of a given fish in the study being alive at a given time.

Summer Survival by Habitat

Though sample size in the Clark Fork (16 fish) is low relative to Upper and Lower Rock Creek (109 and 48 fish respectively), there is a clear trend showing lower survival in the Clark Fork (Figure 3). Summer survival in the Clark Fork (7.6%, 95% CI: 5.4 – 10.5%) is roughly a quarter of that in the Upper Rock Creek (30.8%, 95% CI: 22.1 – 42.9%) and Lower Rock Creek sections (37.1%, 95% CI: 26.7 – 51.7%).

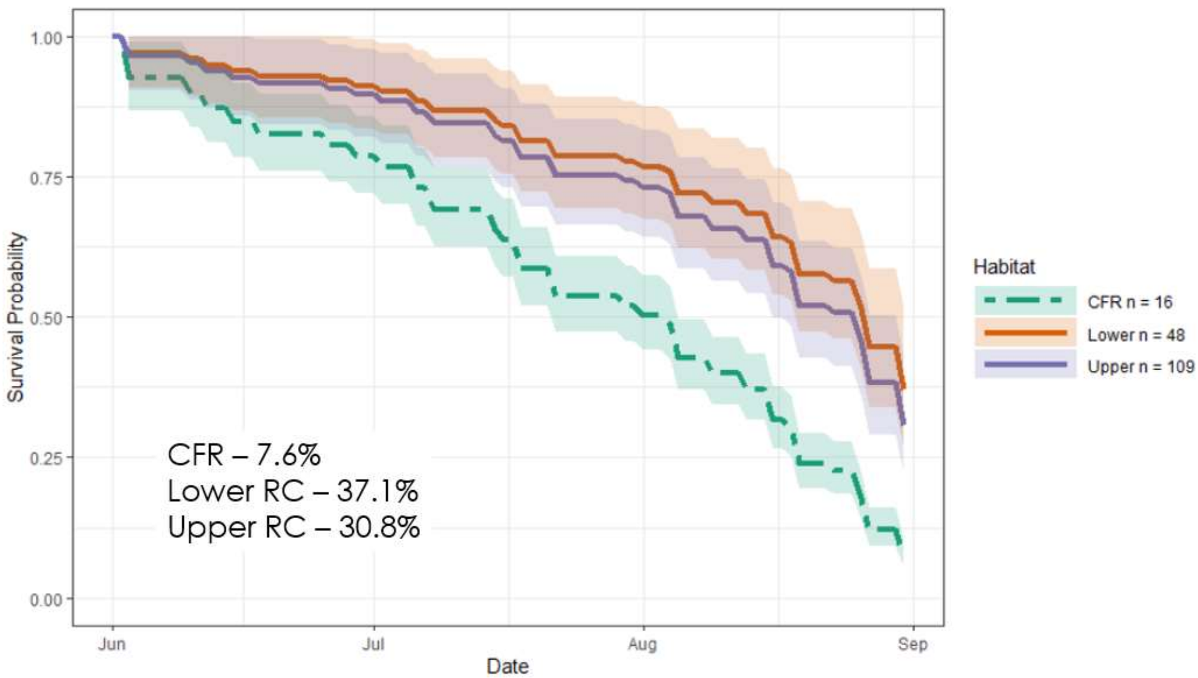

Figure 3: Summer survival probabilities and 95% confidence intervals of fish using the Clark Fork River (CFR, dashed green line), Lower Rock Creek (Lower RC, solid orange line), and Upper Rock Creek (Upper RC, solid purple line) from June 1st through August 31st derived from the Cox Proportional Hazards model. Summer survival probabilities are listed for each section. Sample size for each study section is listed in the legend.

Given the relatively low survival probability for fish spending the summer in the Clark Fork, we wanted to determine potential reasons for significant differences from Rock Creek. Each year of the study, the Clark Fork R. reached temperatures over an 18°C threshold, while the Rock Creek sections rarely exceeded 16ºC. Each summer, the Clark Fork experienced extended periods (3+ weeks) of mean temperatures over 18ºC, typically in late July and early August.

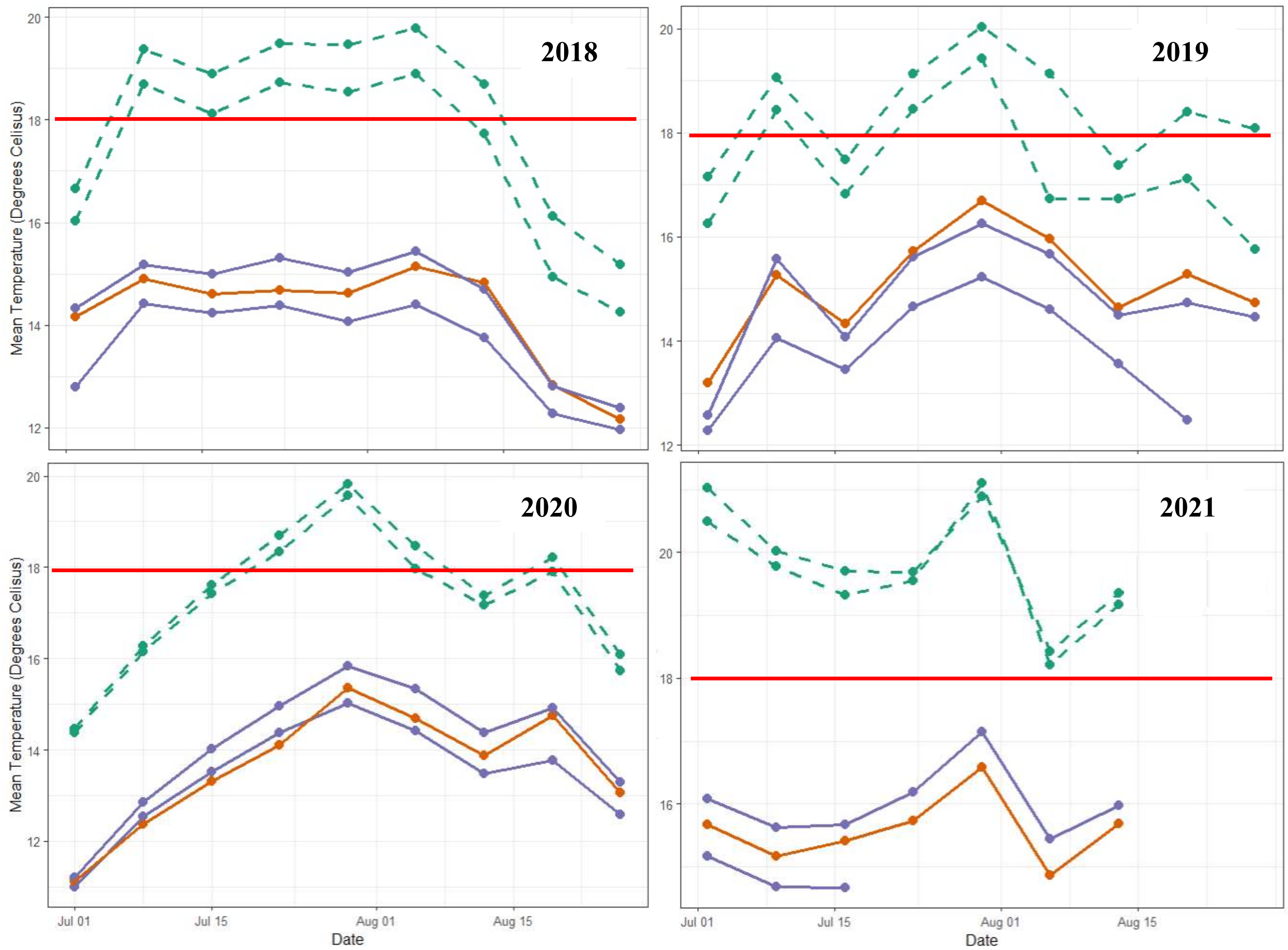

Figure 4: Mean weekly stream temperatures between July 1st and September 1st from 2018-2021 in the Clark Fork R. (green, dashed line), Lower Rock Cr. (solid, orange line), and Upper Rock Cr. (solid, purple line). The red line on each plot represents the 18ºC threshold for stressful temperatures for WCT. The bottom purple line from 2019 ends on August ** as the temperature logger was out of the water past that date. The 2021 data extends to August 16th, except for one Upper Rock Cr. which ends on July 22nd.

So, similar to the analysis of temperature, we wanted to see if there were significant trends of extraordinarily low flows in the Clark Fork during the study period, or if flows tended to stay fairly similar from year to year. And, if we did see low flows, did they also come at times of high stream temperatures, creating periods of very high stress for tagged fish? The lowest discharge values in Rock Creek and the Clark Fork come in August (Table 1). The only year of the study where monthly means are noticeably lower than the 25-year mean is in 2021. Each station, for every month, had discharge values lower than the long-term means in 2021. Otherwise, discharge values throughout the study stayed close to, and sometimes were higher than the long-term mean.

Table 1: Monthly mean discharge (in cubic feet per second) for each of the summer months throughout the study period for the Rock Creek, Drummond, and Turah USGS stations. The 25 year (1997-2021) mean monthly discharge for each station is included for reference.

Location	Year	June	July	August
Rock Creek	25 Year Mean	1672	630	302
	2018	2507	887	407
	2019	1442	550	303
	2020	2103	1113	390
	2021	1491	424	289
Drummond	25 Year Mean	1712	733	355
	2018	3596	1327	488
	2019	1571	776	429
	2020	2569	1621	506
	2021	899	326	333
Turah	25 Year Mean	3608	1478	695
	2018	6593	2599	968
	2019	3199	1467	820
	2020	4872	2907	980
	2021	2622	836	653

Winter Survival by Habitat

Only one fish throughout the study was observed using the Clark Fork during the winter months. This fish perished, so that is why the Clark Fork line drops to 0% survival in March. 68 fish were observed in Upper Rock Creek, while 20 were observed in Lower Rock Creek during the winter months. Due to low frequency of relocations during the winter months, confidence intervals range from 0 – 100% survival probability. The rate of survival for the Upper and Lower Rock Creek sections are 85.2% and 62.7%, respectively. These numbers are high, relative to the survival trends seen in summer (30.8% and 37.1% for Upper and Lower Rock Cr., respectively).

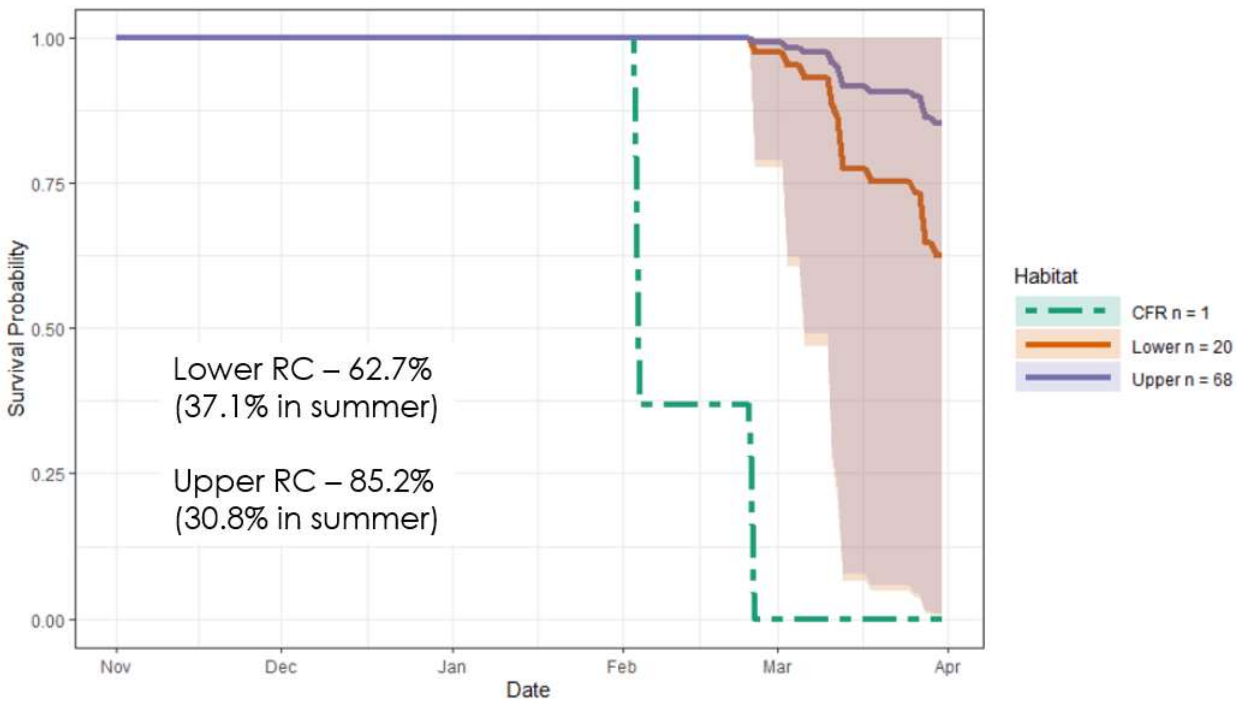

Figure 5: Winter survival probabilities and 95% confidence intervals of fish using the Clark Fork River (dashed green line), Lower Rock Creek (solid orange line), and Upper Rock Creek (solid purple line) from November 1st through March 31st derived from the Cox Proportional Hazards model. Summer survival probabilities in Rock Creek sections shown for reference. Sample size for each study section listed in legend.

DISCUSSION

Our results show that survival is higher in Rock Creek that in the Clark Fork during the summer months, and show that survival is higher (relative to summer) in Rock Creek in the winter. The annual survival rate for all ancestries of *Oncorhynchus spp.* in the entire study area was around 27%. The summer survival probability models for each of the three study sections showed a clear trend that favors Rock Creek for *Oncorhynchus spp.* between June and August. Survival rates for Upper Rock Creek (30.8%) and Lower Rock Creek (37.1%) are both around four times that of the Clark Fork (7.6%). We also estimated winter survival rates high relative to summer survival rates for Upper Rock Creek (85.2%) and Lower Rock Creek (62.7%).

Annual survival of the three ancestries (WCT, RBT, hybrids) was not significantly different (Question 1), so we were able to combine all 190 fish into a single dataset to analyze effects of habitat on seasonal survival. We found that there was indeed a significant impact of seasonal habitat use on survival of fish, especially in the summer where much higher survival probabilities were seen in Rock Creek compared to the Clark Fork (Question 2). Winter survival was also observed to be high in the Rock Creek sections. Using temperature and discharge data, we analyzed trends in each habitat section. We found there to be periods of each summer in the study where temperatures exceeded the 18ºC threshold in the Clark Fork, but did not see significant trends in discharge data. Overall, Rock Creek has far lower summer temperatures throughout the entire mainstem, acting as a suitable foraging stream during warm summer months.

Previous studies comparing survival rates of different WCT and RBT ancestries are essentially non-existent, but many studies have estimated annual survival of different species of cutthroat trout (Mayfield et al., 2019; Sheldon & Richardson, 2022; Uthe et al., 2016). Our annual WCT survival was 25%, with annual survival of all fish at 27%. A British Columbia study on coastal cutthroat trout found annual survival between 19 – 46%, depending on stream (Sheldon & Richardson, 2022). A Montana and Wyoming study on Yellowstone cutthroat trout (*O. clarkii bouvieri*) found annual survival rates of 30 – 58% for larger (> 120 mm total length) sizes of fish (Uthe et al., 2016). In an upper Clark Fork River study, Mayfield et al. (2019) found annual survival of WCT to be 9 – 29%. The upper Clark Fork was divided into three sections in Mayfield et al. (2019), and the section of the study that overlaps our section of the Clark Fork had 12.2% annual survival in WCT. Compared to other studies our annual survival of 27% falls into, or close to, the annual survival ranges of other studies. 27% fits into the ranges for Sheldon

& Richardson (2022) as well as Mayfield et al. (2019), falling just short of the bottom of the range in Uthe et al. (2016) at 30%. Given trends in our seasonal survival probabilities, it is possible that if only the Clark Fork fish had been used in the study, our annual survival would have fallen short of other studies. The high survival in Rock Creek brings up the overall percent of fish surviving on a yearly basis, and creates similar probabilities to other studies. Overall, annual survival in our study was comparable to other cutthroat studies.

Seasonal survival trends in cutthroat have been variable in others studies (Berger & Gresswell, 2009; Mayfield et al., 2019; Sheldon & Richardson, 2022; Uthe et al., 2016). Berger & Gresswell (2009), Sheldon & Richardson (2022), and Uthe et al. (2016) conducted studies on small (first or second order) headwater streams, using passive integrated transponder (PIT) tags to track survival. Like our study, Mayfield et al. (2019) was the only other study on a large river system (the Clark Fork R.) which used radiotelemetry (most similar to our methods). The only study that found the lowest seasonal survival to consistently be in the summer months was Sheldon & Richardson (2022), which was related to times of low flow and potentially the warmest temperatures. The study pointed out the overall lack of habitat availability caused by these factors as the most likely reasons for low summer survival in coastal cutthroat. Similar to Rock Creek, the streams studied in Sheldon & Richardson (2022) rarely reached temperatures beyond 15ºC. This is much different than the Clark Fork, though, which commonly reaches stream temperatures of 18ºC and occasionally over 20ºC. This highlights a key discrepancy with not just Sheldon & Richardson (2022), but also Berger & Gresswell (2009) and Uthe et al. (2016), which are all in high elevation, cool streams that rarely reach high temperatures. Unlike our study, Uthe et al. (2016) found little differences between survival of Yellowstone cutthroat in the winter and summer months in most years. One year in the study (2013) had noticeably lower flows and higher temperatures in the summer, and this was the year where summer survival did drop below winter survival (Uthe et al., 2013). Once again, this study highlights the importance of cold water, as well as summer flows for habitat availability and survival. Even though our discharge values do not show low summer flows during our study period, we do see high temperatures in the Clark Fork every summer. And, even if flows in our study years are not outliers, the lowest flows and highest temperatures of the year tend to be seen in July and August and may lead to low seasonal survival. Berger & Gresswell (2009) found the lowest seasonal survival (60%) of coastal cutthroat in autumn (September 16th to December 15th), with the highest in summer (88%). Though the numbers do not match with our study, the idea of low flows acting as a "survival bottleneck" in the late summer and autumn do resonate in the study. It was found that temperature was weakly associated with survival, but that the months with the highest frequency of low flow events were times of lowest survival due to habitat availability (Berger & Gresswell, 2009).

In the studies listed above, it appears that the size of the stream affects survival greatly. Compared to large streams like Rock Creek and the Clark Fork R., first and second order streams do not have much water (and habitat) to begin with. Come late summer and early fall, habitat availability associated with low discharge is much lower relative to other seasons. That is a key difference to acknowledge with other cutthroat survival studies, considering Rock Creek and the Clark Fork are high order streams. Mayfield et al. (2019) comes as an exception, whose study area overlaps our area. Contrary to others studies (and ours) Mayfield et al. (2019) found WCT survival to be lowest during the spring (April – June): the time of highest stream flow. The lowest survival was linked to high levels of copper contaminants in the upper section of the Clark Fork, which was exacerbated by heavy spring flows. The study saw moderate survival in the summer and very high survival with very few mortalities in fall and winter. The section of the study that overlaps our study section of the Clark Fork had combined spring/summer survival for WCT at 24.4% and fall/winter survival of 90.4% (Mayfield et al., 2019). 24.4% is much higher than our study, where we found 7.6% summer survival in the overlapping section of the Clark Fork. The theme of low flow resulting in low survival, as seen in other studies, did not appear to apply to the Clark Fork. Similar to Mayfield et al. (2019), our study showed winter survival rates much higher (approximately double) than those from the summer in Rock Creek. It appears that summer is a more stressful time in our study area, and our results show that Rock Creek provides high quality overwintering habitat for WCT, RBT, and hybrids.

So, what makes the Clark Fork's summer survival numbers so low compared to Rock Creek, as well as other cutthroat studies? The Clark Fork spent consecutive weeks above 18°C every summer, while Rock Creek temperatures very rarely surpassed 16°C. Bear et al. (2007) found a significant drop in survival in WCT in a lab setting when in water temperatures 18°C and up. Heinle et al. (2021) noted that WCT in the North Fork Flathead River were not observed at temperatures greater than 18°C. Stream temperatures in the Clark Fork going over this threshold would likely force fish to either move into the mainstem of Rock Creek, or they would perish. Discharge data was not particularly telling, as far as being a reason for low survival. Flows during the study period were not noticeably lower than the 25-year average in the Clark Fork (except in 2021). We can confirm with these data that the years of the study did not have abnormally low summer flows, but may suggest that the habitat in the Clark Fork is typically unsuitable for *Oncorhynchus spp.* during summer months. Another factor to consider for survival in the Clark Fork is contamination. Copper mining operations in the 1800s and 1900s left the upper Clark Fork contaminated with mining waste, which has had downstream effects (Mayfield et al., 2019; Phillips & Lipton, 1995). Hansen et al. (1999) found *Oncorhynchus spp.* (cutthroat trout and RBT, specifically) are more sensitive to mining-related contaminants than brown trout, shifting trout populations from *Oncorhynchus spp.* to mostly brown trout. Though contaminant levels in our section of the Clark Fork have been found to be low relative to the uppermost part of the stream (Mayfield et al., 2019), Rock Creek's pristine water quality appears to provide far more suitable habitat for WCT and RBT (Liermann, 2022). Our findings suggest that Rock Creek provides more suitable habitat for *Oncorhynchus spp.* than the Clark Fork, at least in the summer. Rock Creek serves both as high quality overwintering habitat and good foraging habitat in the summer (compared to the Clark Fork).

CONCLUSION

Rock Creek provides non-hybridized, migratory WCT with optimal foraging, migrating and overwintering habitat. The Clark Fork R. does not appear to provide fish with optimal foraging and summer habitat. Given that non-hybridized, migratory WCT are becoming uncommon in large river systems (Muhlfeld et al., 2009; Yau & Taylor, 2013), the importance of protecting habitats such as Rock Creek is very high. Maintaining variable life history forms is important for the future of WCT in the state, promoting population connectivity, genetic diversity, and overall population persistence and resiliency (Heckel et al., 2020). Habitat connectivity is key to persistence of migratory individuals (Heckel et al., 2020; Shephard et al., 2005), and Rock Creek provides pristine water quality and optimal stream temperatures during stressful periods of the year (Liermann, 2022). Shepard et al. (2005) highlights the importance of stringent land use practices for protecting WCT, and, compared to the Clark Fork, Rock Creek is far more suitable. The Clark Fork flows alongside major highways and interstates in open valleys, while the mainstem of Rock Creek flows along a dirt road in a more confined valley and shaded canyon setting. For the success of future conservation efforts, Williams et al. (2011) suggests large scale protection of watersheds and aquatic habitats. Keys to meeting this objective include habitat complexity, diversity and connectivity; protecting all life histories; protecting a large enough area to promote long-term persistence of the desired species; and use of sustainable management practices (Williams et al., 2011). Our study builds a better understanding of how WCT survival relates to habitat use and can be useful to help protect and prioritize habitats.

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