

RISK OF MORBIDITY AND MORTALITY TO NATIVE TROUT ON
THE FORT HALL INDIAN RESERVATION, IDAHO, DUE TO
INCREASED STREAM TEMPERATURES

by

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DEDICATION

I dedicate this body of work to my wife, children, and future grandchildren.

ACKNOWLEDGEMENTS

I first acknowledge the Creator. In my native Cree language we say “Hiy Hiy Kisemahnito” which translates to “Thank you kind spirit”. I am thankful for being allowed the opportunity to be involved with and to complete this body of work with everyone involved. I want to acknowledge and thank my beautiful wife Rochelle Jade LodgePole and our children who include our sons Tyrenn James Parker LodgePole, Kayahn Monte LodgePole, and daughters Maryenn Dinae, and Roselynn Ronae LodgePole. Their support and encouragement for me throughout the whole process of completing this body of work was second to none and for that I will be forever grateful. I would like to acknowledge and thank my graduate committee members which includes Dr. Clifford Montagne (Co-chair), Dr. Robert Peterson (Co-chair), Dr. Walter Fleming, and Dr. Lucy Marshall. Their support, guidance, expertise, and professionalism in me completing this work was great and very much appreciated. Lastly I want to acknowledge and thank Bonnie Sachatello-Sawyer of Hopa Mountain, all the folks at the Greater Yellowstone Coalition, the Fort Hall Tribal Council, and all my Fort Hall contacts and the departments in which they represent which include Chad Colter, Hunter Osborne, Candon Tanaka. Funding was provided by the National Science Foundation (Native Science Fellows Program), SLOAN Foundation, Epscor, Stone Child College (STEM and Chippewa Cree Higher Education programs).

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ABSTRACT

Climate change is now happening faster than ever. The Fort Hall Indian Reservation (FHIR), is located in Bingham, Power, Bannock, and Caribou Counties, Idaho. To estimate the quantitative risk of morbidity and mortality posed to Yellowstone Cutthroat Trout *Oncorhynchus clarki bouvieri* on the FHIR, stream temperatures, or at the very least, a robust estimate of stream temperatures, was needed. The first objective was to examine what stream temperature data were available. The second objective was to obtain elevation values for stream temperature monitoring sites within the FHIR. This helped in the third objective, which was to develop a regression model to predict stream temperatures. The fourth objective was to document thermal preferences of YCT. Cross-referencing thermal thresholds of YCT and stream temperatures allowed for the fifth and sixth objective, which was to create a deterministic and probabilistic risk assessment. The seventh objective was to map out the risk assessment and graphically display risk associated with each major stream reach within the FHIR. The results of this study indicate that a substantial amount of suitable YCT habitat within the FHIR will likely be lost due to increased stream temperatures, a direct result of global climate change. At this local scale the bulk of the habitat loss can be expected in the lower elevation areas of the FHIR. Mid to high elevation areas will also be negatively affected but not as much as the lower elevation areas. This effort led to the understanding that stream temperatures for the current time frame have been increasing as a result of climate change. With the projected increases in future July stream temperatures the optimal habitat for YCT will be significantly diminished as well. Therefore, this study may serve as a call to action to all interested parties within the FHIR, State of Idaho, and the Greater Yellowstone Ecosystem. With the gleaned information and understanding of how stream temperatures will put YCT at higher risk of temperature related morbidity and mortality, it is up to the risk managers of the greater FHIR and the FHIR to take whatever action they deem necessary in their unique environmental management responsibilities.

INTRODUCTION TO THESIS

The Fort Hall Indian Reservation (FHIR), home to the Shoshone Bannock Tribe (SBT) is located in Bingham, Power, Bannock, and Caribou Counties, Idaho (Figure 1). Of the entire 2,200 km² FHIR, 97.9% is tribally owned, 2.1% is non-Indian owned (USDA, et al. 2006). The FHIR situated in the Columbia River basin and contains five separate watersheds: Bannock Creek, Portneuff River, Blackfoot River, Ross Fork, and Snake River Plain (USEPA 2008). All of these watersheds discharge directly or indirectly into the American Falls reservoir (USEPA 2008). The watersheds are named after the principal streams within the watershed delineation.

The FHIR has exceptional water quality and supports a range of environmentally diverse aquatic biota including the naturally occurring native Yellowstone cutthroat trout (YCT) *Oncorhynchus clarki bouvieri* (USDA, et al. 2006). This native trout species has a very high level of cultural, and economic significance on the FHIR and the greater FHIR area (Gresswell 2006). As such, there is a vested interest in their preservation and conservation from the SBT, the State of Idaho, and the area of the Greater Yellowstone Ecosystem (GYE). The GYE provides much habitat for YCT. Because the FHIR is one of the two Indian reservations within the boundaries of the GYE, unique management responsibilities and opportunities on tribal land could be explored.

“Climate is the set of long term, average meteorological conditions that occur over several decades or longer. Unlike weather, which fluctuates greatly in the short term and is difficult to predict, climate is relatively stable, and most organisms within an ecosystem have adapted to its predictable rhythms. As a result, climate is a driving force

behind many ecological processes. For example, temperature and precipitation regimes strongly influence the intensity and timing of stream flows, which are important factors in the aquatic components of agricultural and wild land ecosystems” (Isaak, et al. 2010).

Climate change is now happening faster than ever (IPCC 2013). Because of their isolated and remote placement, many Indian reservations have geographies most susceptible to the effects of a changing climate. These areas are also the traditional tribal lands of indigenous communities, as is the case within the FHIR (Tsosie 2007). As such, effects of increasing temperatures on fisheries habitat may pose some of the greatest environmental quality effects on tribal sustainability and quality of life.

Water temperature, which fluctuates spatially and temporally, plays a fundamental role in aquatic ecosystem health, influencing the distribution, reproduction and survival of many stream-dwelling species (Dunham, Reiman and Chandler 2003). Salmonid species (i.e. YCT) in particular are severely influenced by fluctuations in stream temperature, stream flow, and other physical habitat conditions (J. E. Williams, et al. 2009). Salmonids are extremely susceptible to a warmer drier climate and can be important gauges of effects of climate change on ecosystem health (Pederson, et al. 2010). Because of their evolutionary development in very cold aquatic ecosystems and the reliance of their body temperature on surrounding habitats, YCT, in particular, have a narrow tolerance for thermal fluctuations in streams and rivers (Gresswell 2006).

A strong and slow-melting snowpack historically delivers a steady flow of cold, oxygen-rich water throughout the hottest months of the FHIR. These cool conditions are critical to the survival of YCT. However, over the past decade fishery managers have

witnessed increases in stream temperatures due to warmer air temperatures (D. J. Isaak, et al. 2010). With peak spring runoff in many of the FHIR's waterways occurring 10 to 20 days earlier, the resulting warmer and lower summer flows are detrimental for YCT.

Drought is expected to intensify, stream-scouring winter floods are likely to become more common in lower-elevation areas, wildfires in the higher alpine elevations will be more frequent and severe, and stream temperatures are expected to increase (J. Williams, et al. 2009). YCT are already reduced and isolated in many locations of the FHIR, and climate change will exacerbate existing stressors. Some high-elevation areas of the FHIR ecosystem will provide a critical refuge as low-elevation streams and rivers warm and lose base flows (J. E. Williams, et al. 2009). If YCT are to continue to inhabit the waters of the FHIR, managers and citizens must make a new commitment to understand what impacts climate change is having and will have on stream temperatures at this local scale.

The purpose of this study is to understand what effects climate change is having and will have on stream temperatures at this local scale and on subsequent risk of morbidity and mortality to YCT. This will in turn aid in the management and decision making process regarding YCT habitats. This study will use available stream temperature data and climate change models to identify risk of morbidity or mortality for streams within the FHIR.

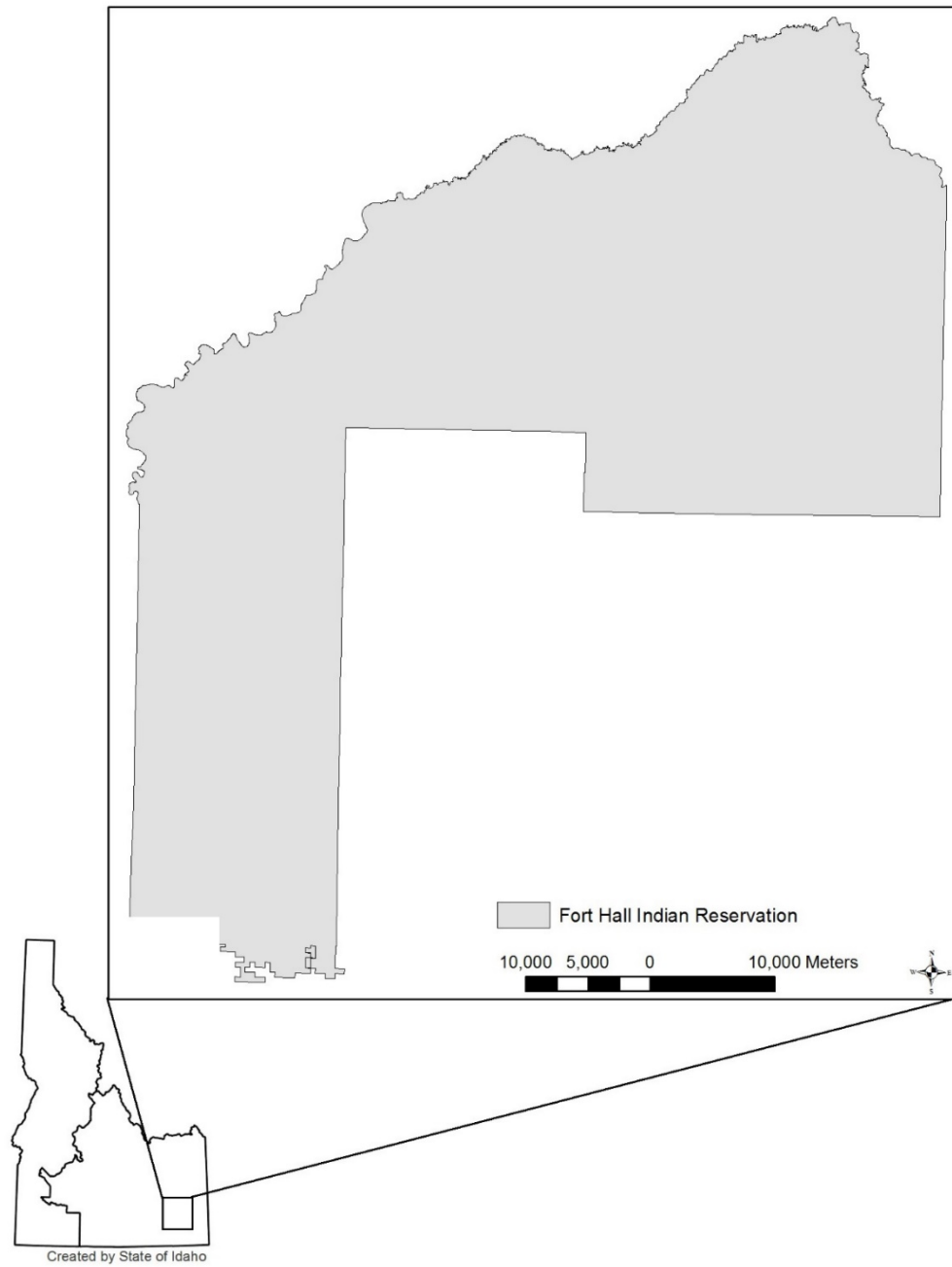


Figure 1: Fort Hall Indian Reservation of Southeast Idaho. Study Area.

MATERIALS AND METHODS

Objectives

To estimate the quantitative risk of morbidity and mortality posed to YCT on the FHIR, stream temperatures, or at the very least, a robust estimate of stream temperatures, is needed. With the understanding that elevation has a direct influence on air temperature, the obtainment of elevation for stream temperature monitoring sites within the FHIR will be critical for developing a regression model to estimate maximum daily July stream temperatures.

The first objective is to examine what stream temperature data are available. The second objective is to obtain elevation values for stream temperature monitoring sites within the FHIR. This will help in the third objective, which is to develop a regression model to predict stream temperatures. The fourth objective is to document thermal preferences of YCT. Cross-referencing thermal thresholds of YCT and stream temperatures will allow for the fifth and sixth objective, to create a deterministic and probabilistic risk assessment. The seventh objective is to map out the risk assessment and graphically display the risk associated with each major stream reach within the FHIR.

The eighth and final objective in the completion of this study will then be to share the results with interested tribal members and officials of the FHIR with hope that it will aid the SBT in maintaining the critical waterways that have sustained YCT.

Study Area

The FHIR is located west of Interstate 15 approximately halfway between Pocatello and Blackfoot, Idaho and covers roughly 2,200 km² in southeastern Idaho (USDA, et al. 2006). The FHIR consists of two mountainous regions with broad valleys and a lowland area of arid plains adjoining the Snake River (Mansfield and Heroy 1920) (Figure 2). The variance in elevation is roughly 1,000 meters, and the larger valleys span a range from about 1280 to 1,800 meters in elevation. The drainages are all tributary to the Snake River. The semiarid climate receives around 18 to 30 centimeters of precipitation annually which is evenly dispersed throughout the year. Extremely high atmospheric temperatures occur frequently in the summer.

The FHIR is situated entirely within the Snake River Drainage. The Northwest boundary is the Snake River, extending a distance of about 40 kilometers east from the outlet of the Blackfoot River to the Portneuf River.

Native Trout on the Fort Hall Indian Reservation

YCT are the most plentiful and broadly distributed subspecies of inland cutthroat trout and are the only trout species native to the FHIR (Figure 3) (Varley and Gresswell 1988). Of all trout in the upper Snake River basin, YCT are the most plentiful and extensively disseminated type (Meyer, Schill and Lamansky, Jr. 2006). As the state Fish for Idaho, the YCT symbolizes the very nature of pristine lakes, rivers, and streams of the West (GYSLC 2014). As inferred by their name, YCT are readily distinguished by

outstanding red slashes underneath their inferior jawbone (Idaho Chapter of the American Fisheries Society 2014).

They have evolved in fairly barren, cold ecosystems, and because of this the YCT are known for being extraordinarily aggressive and opportunistic feeders (Varley and Gresswell 1988). This is a characteristic that makes them very popular with anglers (Idaho Chapter of the American Fisheries Society 2014). To persist, YCT require cold, oxygen-rich water, diverse stream habitat, ample cover, and clean gravel substrate which makes them very sensitive to habitat changes (Idaho Chapter of the American Fisheries Society 2014).

Yellowstone Cutthroat Trout Thermal Preference

The YCT have evolved in very cold oxygen-rich stream and riverine ecosystems (Thurow and King 1994). They overwinter eight months out of the year in higher alpine regions of the GYE and the FHIR. Their optimal thermal threshold lies between 5.5 and 16.99°C (Bear, McMahon and Zale 2005). Within this optimal thermal threshold the YCT are able to thrive and persist as a species. In this sense, thrive means that the YCT will lay eggs and reproduce many offspring, feed and continue to pass on their genetic legacy as fish within their native waterways of the FHIR.

When exposed for seven days or more to the temperature ranges of 17 – 20.99°C YCT will exhibit morbid behavior (Bear, McMahon and Zale 2005). Morbidity in this sense means that the fish will not readily reproduce. Due to the lack of oxygen in the water at this temperature their metabolism will decrease and will display physical signs

of biomass depletion (Varley and Gresswell 1988). Their general activity will also decrease, as a result the fish will display signs of lethargy, a lowered rate of movement throughout the waterways they inhabit. This in turn leaves the fish more prone to predation and overall population decline. It also decreases their ability to compete and scour the streams and rivers in which they inhabit for food.

The upper thermal threshold for YCT is 21°C (Bear, McMahon and Zale 2005). When exposed for seven days or more to water temperatures of 21°C or higher fish populations decline sharply (Table 1).

Stream and Atmospheric Temperature Database

Stresses to fish physiology due to warm water temperatures and low base flows have substantial bearing on fish growth, behavior, and habitat selection (McMahon and Selong 2001). The available stream and atmospheric temperature data show that the warmest water temperatures of the year in the FHIR occur during July. Since, YCT migrate to natural spawning streams in the headwater, high elevation reaches of the FHIR during spring and summer months, this study focuses on the warmest month of the year, July.

An initial step for this study was to compile available data. The Water Resources Department (WRD) of the FHIR provided a spreadsheet that contained stream names, maximum daily July stream temperatures in degrees Celsius, along with latitude and longitude coordinates for 59 stream temperature monitoring sites along the major streams

located within the FHIR from July 2000 to July 2013. These data were sparse and sporadic.

Other stream temperature data came from two United States Geological Survey (USGS) gauging stations on and very near the FHIR. These gauging stations were established by the USGS, in collaboration with the State of Idaho and other governmental entities (Mansfield and Heroy 1920). A station established in 1910 just below the outlet of the Blackfoot River documents water temperatures of the Snake River along the western border of the reservation. The Neeley ID station, established in 1906, measures the effects of spring water additions along with the Portneuf River and Bannock Creek.

The station at Neeley, which was established March 17, 1906, is the oldest on the river, and the records which have been obtained there is of great value in the interpretation of the hydrologic characteristics of the river and in the formulation of plans for its utilization (Mansfield and Heroy 1920). The hydrometric data obtained at the Neeley station have been published in the water-supply papers of the USGS (Mansfield and Heroy 1920). The Snake River probably receives a relatively small amount of direct inflow from the Fort Hall Indian Reservation, but its tributaries, Blackfoot River, Portneuf River, and Bannock Creek, which drain most of the reservation, are important contributing streams (Mansfield and Heroy 1920). These two sites are where most of the stream temperature data used in this study were obtained.

Elevation plays an important role in surface atmospheric temperatures (Legates and Willmott 1990). For model calibration purposes, the maximum daily air temperature for the month of July for the years 2000 to 2013 at two different elevations was obtained.

A low elevation (1354m) dataset was obtained from a Bureau of Reclamation Agrimet station located on the FHIR and a high elevation (1978m) was obtained from a Natural Resource Conservation Service Snow Telemetry (SNOTEL) weather station located on the Wild Horse Divide very near the FHIR.

The resultant database consisted of two air temperature spreadsheets and 59 separate spreadsheets for each stream temperature monitoring site along the major waterways of the FHIR. The combined spreadsheets totaled 928 data points from 61 unique sites. These data were then summarized by two temperature metrics. The first metric was defined as the weekly mean stream temperature for the weeks within the time frame of 1-31 July. The second metric was defined as the yearly weekly maximum average July stream temperature (YWMAJST), which is the highest seven day moving average of maximum daily stream temperatures. The mean weekly temperatures provide an overall indication of thermal suitability and optimal conditions for growth; and the YWMAJST provides an indicator of the duration of seasonal extremes (Isaak, et al. 2010).

Elevation

The environmental data from the FHIR WRD and the USGS sites were imported into ArcMap (ArcGIS 10.2, ESRI Inc. Redlands, CA) and converted into a point feature class shape file titled “Monitoring_Stations” (Figure 4). This shape file was in the NAD 83 projected coordinate system. Spatial datasets for land ownership (polygon feature class), streams (line feature class) and major water bodies (polygon feature class) came

from the website <http://giscenter.isu.edu/>, the GIS Training and research center at Idaho State University, and the SBT GIS program. These data were converted into the NAD 83 projected coordinate system. The ISU data are free and available for public use.

The land ownership data set was used to obtain the FHIR boundaries. Individual records from the attribute table that represented the area of the FHIR were used to create the boundary. Subsequently, these selected items were clipped from the dataset leading to the creation of the “FortHallArea” shape file. This data set was then spatially overlaid on the streams and major water bodies’ data sets. Features from these datasets were then selected by “location” within the FHIR and “clipped” to create the “forthallstreams” and “forthallmajorwaterbodies” shape files.

Global Digital Elevation Model (GDEM) files were downloaded from the USGS earth explorer website. Raster data included advanced space born thermal emission and reflection radiometer (ASTER) global digital elevation model (GDEM) version 2 .tif files (image files). Four of these raster type tiff image GDEM files were obtained and downloaded covering the study area of the FHIR. Adding these four study area GDEM files to ArcMap, allowed the creation of a raster image mosaic which was converted to the grid format using ArcMaps Data conversion tool. Subsequently, the mosaic was stitched together into one raster GDEM grid file by using ArcMaps “mosaic to single raster” tool. This process led to the creation of a new raster which was named “elev”. The elev raster was subsequently converted into a hillshade raster to be used to add textural richness to the final map layout.

Elevation values from the “elev” GDEM raster were extracted using ArcMap’s “extract to points” tool. In this process, the input feature class was the “Monitoring_Stations” shape file and the input raster was the elev GDEM file. This led to the creation of a new shape file which was named “monitoringwelev”. The resulting attribute table of this point feature class displayed the added field of elevation (in meters) at each of the 59 stream temperature monitoring points.

Elevation work flow summary:

1. Imported as ArcMap
2. Converted to a point feature class
 - a. Monitoring_Stations.shp
3. ISU and SBT sources
 - a. Land ownership, streams, water bodies
 - b. Land ownership determined Reservation boundaries
 - i. FortHallArea.shp
 1. Then overlaid on stream and water
 2. Forthallstreams, forthallmajorwaterbodies.shp
4. GDEM raster data
 - a. Thermal emission and reflection radiometer
 - b. Global digital elevation
 - c. Elev, hillshape
5. Monitoringwelev for 59 points

Stream Temperature Model

To estimate the quantitative risk of morbidity and mortality posed to YCT on the FHIR, stream temperatures, or at the very least, a robust estimate of stream temperatures was needed. The data obtained from the FHIR WRD were not sufficiently complete to conduct the risk assessment. Although air temperature and elevation both influence stream temperature, air temperature is the most important (Sahoo, Schladow and Reuter 2009). To show influence of air temperature on stream temperature, a simple linear regression model (SLRM) regressing stream temperature on air temperature from two different elevations was developed (Morrill, et al. 2005). Less important variables of insolation, solar radiation, cloud cover, land use, streambed width and vegetation were ignored because air temperature and elevation are sufficient indicators of stream temperature to carry out the needed analysis.

The SLRM predicted maximum daily stream temperatures and bolstered the integrity of the incomplete dataset for the 59 stream temperature monitoring sites within the FHIR. To obtain estimates of the regression parameters for the SLRM, stream temperature observations from the 59 monitoring sites were regressed on measured air temperatures from weather stations at two different elevations: a low elevation site (A) and a high elevation site (B) elevation.

From the time period July 1-31 from the years 2000-2013, maximum daily stream temperature observations from sites where elevation are within 500 meters of low elevation site (A) were paired with observations of maximum daily air temperatures on the same day from low elevation site (A). Similarly, maximum daily stream temperature

observations from sites where elevation are within 500 meters of high elevation site (B) were paired with observations of maximum daily air temperatures on the same day from high elevation site (B) (Figure 5). This was done because for a ~500 meter change in elevation you can expect to observe a change in atmospheric temperature of about 1.8°C (Humphreys 1920). This approach is very appropriate because the variance in elevation of the FHIR is roughly 1000m. With the paired maximum daily July stream and air temperature data, the SLRM model was calibrated.

Once the SLRM was developed and calibrated, it was used to predict stream temperatures for the range of sites and years used in the calibration to complete the dataset. An X and Y axis scatterplot of all the stream and air data was produced (Figure 6) and to view overall trends a trend line was added to display a relationship between stream and air temperature. From this point, a SLRM regressing stream temperature on air temperature from low and high elevations was fit in the computational statistical computer software package, R (CRAN version 3.0.1, University of California, Berkeley, CA). Specifically, the model fit was:

$$\mu \{t_s|t_a\} = \beta_0 + \beta_1 t_a$$

Which is read as follows: the estimated mean (μ) maximum daily July stream temperature t_s given t_a is described by the relationship $\beta_0 + \beta_1 t_a$. Where t_s is stream temperature, t_a is atmospheric temperature, β_0 is the estimate of the slope of the linear relationship, and β_1 is the estimate of the intercept. From this SLRM all the necessary summary statistical information was obtained. The summary statistics of the SLRM gave estimates of the true β_0 and β_1 with their standard errors and 95% confidence intervals. A

plot of the residual standard error was created to assess the assumption of constant variance.

Future Stream Temperature Predictions

Maximum daily stream and atmospheric temperature data were obtained for 59 stream temperature monitoring sites along the major streams for the month of July of the years 2000-2013 on the FHIR. These base line data are categorized as the “Current” time frame. Stream and atmospheric temperatures were paired to calibrate a SLR model to predict additional values to supplement the incomplete data set which came from the FHIR’s WRD. These data estimate stream temperatures during the study period with a 95% degree of confidence. However climate change is now happening faster than ever (IPCC 2013).

It is estimated that average maximum daily atmospheric temperatures will increase by about 1.6°C within 50 years (IPCC 2013). This increase in atmospheric temperature will correlate directly to an increase in average maximum daily stream temperatures (D. J. Isaak, et al. 2010). For that reason, to simulate a 50 year future climate warming scenario, 1.6°C was added to the current time frames air temperatures within the FHIR at both high and low elevations. This future scenario was categorized as the “+50 Year” time frame. Using the calibrated SLR model, stream temperatures were then regressed on the +50 year air temperatures to obtain +50 year mean maximum weekly stream temperatures and YWMAJST estimates according to the following relationships:

$$\mu_{+50} \{t_{s+50}|t_{a+50}\} = \beta_{o+50} + \beta_{1+50}t_{a+50}$$

Where t_{s+50} is the +50 year stream temperature, t_{a+50} is the +50 year atmospheric temperature, β_o is the estimate of the slope of the linear relationship, and β_1 is the estimate of the intercept.

It is estimated that average maximum daily atmospheric temperatures will increase by about 6°C within 100 years (IPCC 2013). This increase in atmospheric temperature will correlate directly to an increase in average maximum daily stream temperatures (D. J. Isaak, et al. 2010). For that reason, to simulate a 100 year future climate warming scenario, 6°C was added to the current time frames atmospheric temperatures within the FHIR at both high and low elevations. This future scenario was categorized as the “+100 Year” time frame. Using the calibrated SLRM, stream temperatures were then regressed on the +100 year time frame atmospheric temperatures to obtain +100 year mean maximum weekly stream temperatures and YMAJST estimates according to the following relationships:

$$\mu_{+100} \{t_{s+100}|t_{a+100}\} = \beta_{o+100} + \beta_{1+100}t_{a+100}$$

Where t_{s+100} is the +100 year stream temperature, t_{a+100} is the +100 year atmospheric temperature, β_o is the estimate of the slope of the linear relationship, and β_1 is the estimate of the intercept.

Risk Assessment

Risk assessment is a framework that estimates the likelihood that adverse ecological effects might occur or are occurring as a consequence of exposure to one or

more environmental stressors (USEPA 1992a). In this case, risk assessment is the quantitative estimation of risk of morbidity and mortality YCT face as a consequence of exposure to increased stream temperatures. This assessment was completed to understand and predict the thermal suitability of the streams and rivers of the FHIR for YCT. This risk assessment also provides specific information on risk to environmental managers.

This risk assessment was based on two objectives: characterization of effects and characterization of exposure. These provided the focus for completing a two phase risk assessment: deterministic and probabilistic risk characterization. The effects endpoints, YCT's morbidity thermal threshold lies within 17 – 20.99°C (Bear, McMahon and Zale 2005). When exposed to more than for seven days to this temperature range, YCT will exhibit morbid behavior (Bear, McMahon and Zale 2005). In this sense, morbid means that fish populations will not readily reproduce. Due to the lack of sufficient oxygen in the water at this temperature their metabolism will decrease. The fish will then display physical signs of biomass depletion (J. Williams, et al. 2009). General physical activity of fish populations will also decrease, as a result populations will display signs of lethargy; lowered rate growth and movement throughout the waterways they inhabit leaving the fish more prone to predation and overall population decline. It also decreases their ability to compete and scour the streams and rivers in which they inhabit for food.

YCT's mortality thermal threshold is $\geq 21^{\circ}\text{C}$ (Bear, McMahon and Zale 2005). Due to the depletion of oxygen levels, growth of algae, bacteria, and other parasitic life forms in warmer waters, when exposed for seven days or more to water temperatures of 21°C or higher, fish populations decline sharply.

Further, the characterization of exposure, elaborated above, refers to the mean weekly maximum daily stream temperatures and YWMAJST found within the FHIR and the thermal threshold of morbidity and mortality YCT have within their enveloping thermal habitats. Exposure to these thermal thresholds within the waterways of the FHIR for seven days or greater determines what the risk of morbidity and mortality is to YCT.

Deterministic Risk Assessment

Utilizing the original and supplemented maximum daily stream temperature data sets, a deterministic risk assessment was conducted. It was completed for the current, +50 year, and +100 year time frames. The YWMAJST for the streams of the FHIR were cross referenced with the optimal, morbidity, and mortality thermal thresholds of YCT. Streams that displayed a temperature range from $<17^{\circ}\text{C}$ were categorized as “Low” risk streams. Streams with a temperature range from $17\text{-}20.9^{\circ}\text{C}$ were categorized as “Medium” risk streams. And streams that displayed a temperature range from $\geq 21^{\circ}\text{C}$ and above were categorized as “High” risk streams.

In this categorical risk setting, Low risk encompasses the optimal thermal threshold for YCT. Medium risk encompasses the morbidity thermal threshold for YCT. And high risk streams encompass the mortality thermal threshold for YCT.

Probabilistic Risk Assessment

There are many methods to complete a probabilistic risk assessment. The method chosen for this study was a Monte Carlo Analysis (MCA). The basic objective of this MCA was to quantitatively characterize the uncertainty and variability in estimates of the

risk of exposure to morbidity and mortality thresholds for YCT by the current, +50 year, and +100 year mean weekly maximum July stream temperature (Risk Assessment Forum 1997).

An MCA is a computer-based method of analysis utilizing statistical distribution sampling techniques to obtain a probabilistic calculation to the solution of a mathematical equation or model (Peterson, Barber and Schleier 2011). This MCA (Crystal Ball 11.1.2.3.000; Oracle, Redwood Shores, CA) was used to estimate the Risk Quotient (RQ) and input variables which were used to determine the RQ. Specifically, the equation used to obtain the RQ is:

$$RQ = \text{Stream Temperature} \div \text{YCT Threshold Temperature}$$

Where RQ is the ratio of stream temperature to YCT thermal thresholds. Specifically, stream temperature is the statistical distribution of weekly maximum July stream temperature. The YCT threshold temperature is the statistical distribution of thermal thresholds of morbidity and a single value temperature for mortality (Bear, McMahon and Zale 2005).

The stream temperature input variables were the statistical distributions for each of the 59 stream monitoring sites were fit in Crystal Ball. The distributions in the lower elevation stream temperature monitoring sites of the FHIR were beta distributions and the higher elevations were gamma distributions. Studies have shown that YCT display morbid behavior within the temperature range of 17°C and 20.9°C because of this the morbidity thermal threshold for YCT was a uniform distribution to account for uncertainty about the temperature at which YCT experience morbidity. The mortality

threshold was a single value, 21°C, and no distribution was used because there is little uncertainty or variability associated with this value (Bear, McMahon and Zale 2005).

Probabilities of incidence of RQ values were determined by extracting values randomly from the statistical distribution of each input variable used to calculate the RQs. Each of the input variables was sampled so that each input variable's distribution shape was reproduced. Then, the variability for each input was proliferated into the final output of the model so that the model output reflected the probability of values that could occur. Analyses were performed using 30,000 iterations to calculate percentile values and other statistical measures for estimates of risk.

Geodatabase and Mapping

Once all modeling procedures were complete, the final results were converted into a geodatabase and imported into ArcMap 10.2. The resulting geodatabase included the monitoring site name, elevation, stream temperature estimator β_0 & β_1 coefficients, mean weekly maximum daily stream temperatures, YWMAJST, deterministic risk results, and probabilistic risk results for the current, +50, and +100 year time frames for all 59 stream temperature monitoring sites within the FHIR. This final geodatabase table was prepared so it could be readily joined via spatial join in ArcMap10.2 (a technique that joins databases to shape files' attributes within arc map) to the existing major waterways shape file layer obtained from the SBT's GIS program.

In July, YCT are not found at elevations below 1460 m (Thurow and King 1994). For this reason, stream reaches that are at and below this elevation were displayed in

black line segments and overlaid upon all subsequent mapping procedures. This color denotes that focus of the results in terms of YCT management decision making process can be made in stream reaches that are higher than this elevation (Figure 7). Also, this shows which streams most likely contain YCT in July relative to the current and predicted risk.

For the risk assessment, mapping procedures were completed first for the deterministic component. This included symbolizing all the waterways with appropriate colors for the risk categories. Low risk, or thermally optimal ($5.5 - 16.99^{\circ}\text{C}$) streams were colored blue. Medium risk, or streams determined to be within the bounds of morbidity ($17 - 20.99^{\circ}\text{C}$) were colored orange. And high risk, or streams determined to be within the bounds of mortality ($\geq 21^{\circ}\text{C}$) were colored red. This procedure was completed for the current, +50 year, and +100 year time frames (Figures 9,10,11).

Next, mapping of the probabilistic risk analysis was completed. This process included appropriate colors for symbolizing all the waterways in such a way that displayed a color schema very representative in terms of the probabilistic risk assessment first in terms of morbidity, and second in terms of mortality. Streams that were determined to experience mean weekly maximum stream temperatures of $17 - 20.99^{\circ}\text{C}$ (YCT morbidity threshold) 0 – 19.99% of the time in July were colored blue, 20 – 39.99% of the time were colored green, 40 – 58.99% yellow, 60 – 58.99% orange, and 80 – 99.99% red (Figures 12,13,14).

Similarly, maximum daily stream temperatures at or above 21°C (YCT mortality threshold) 0 – 19.99% of the time in July were colored blue, 20 – 39.99% of the time

were colored green, 40 – 58.99% yellow, 60 – 58.99 orange, and 80 – 99.99% red (Figures 15,16,17).

Table 1: Thermal Thresholds for Yellowstone cutthroat trout

Yellowstone Cutthroat trout (°C)	
5.5 - 16.99	Optimal
17 - 20.99	Morbidity
≥ 21	Mortality

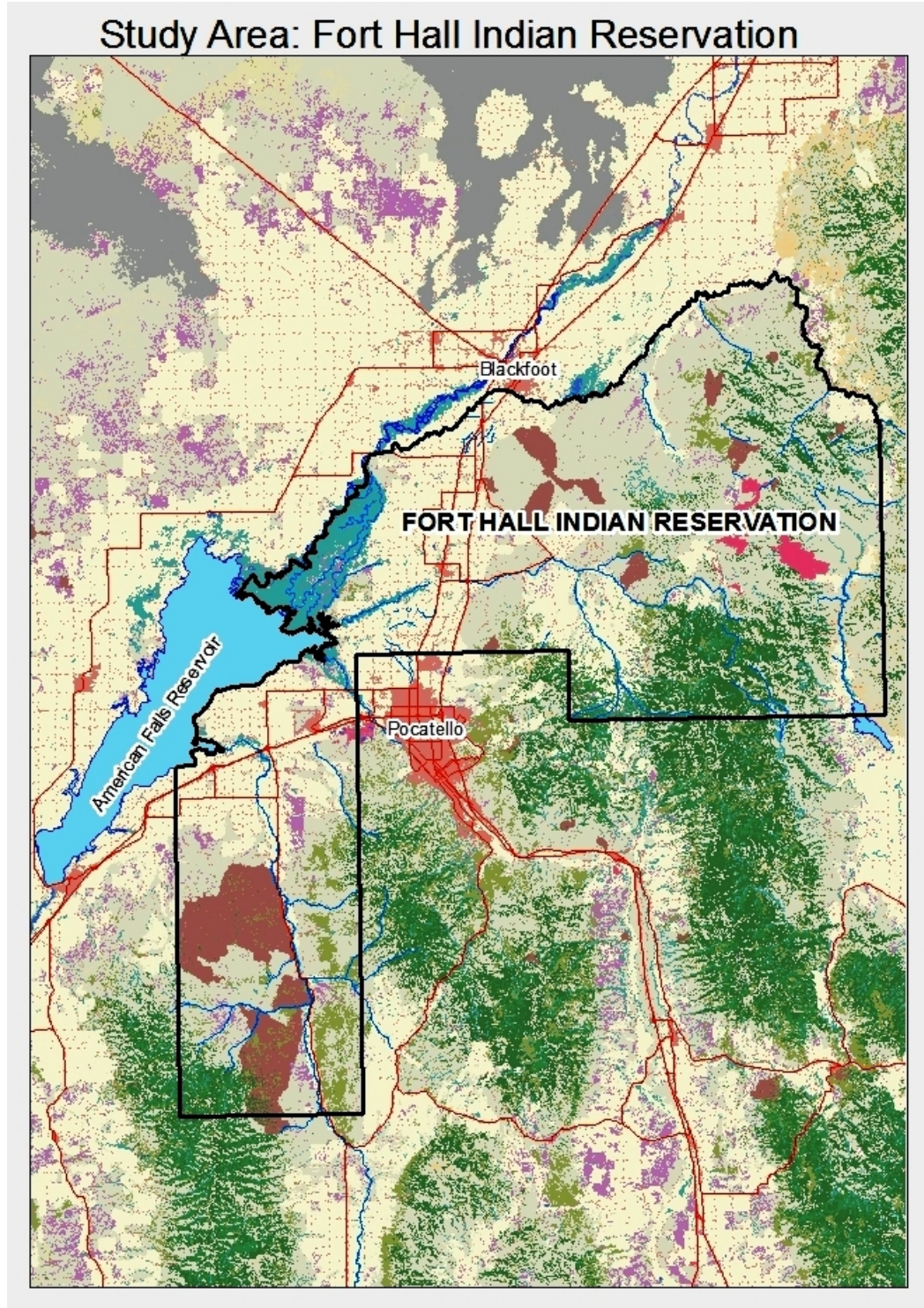


Figure 2: Fort Hall Indian Reservation. Textural map illustrating the description of the study area.



Figure 3: Yellowstone Cutthroat Trout, *Oncorhynchus clarki bouvieri*.

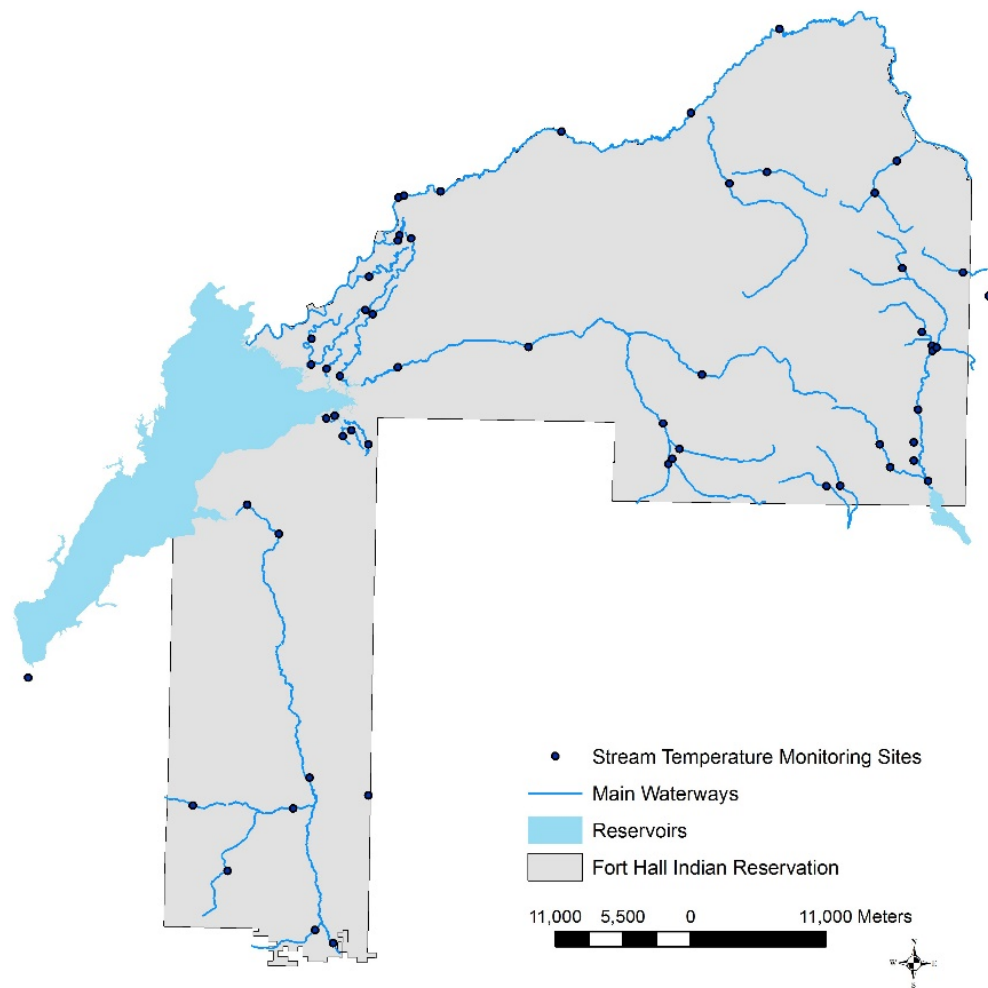


Figure 4: Stream temperature monitoring sites on the Fort Hall Indian reservation

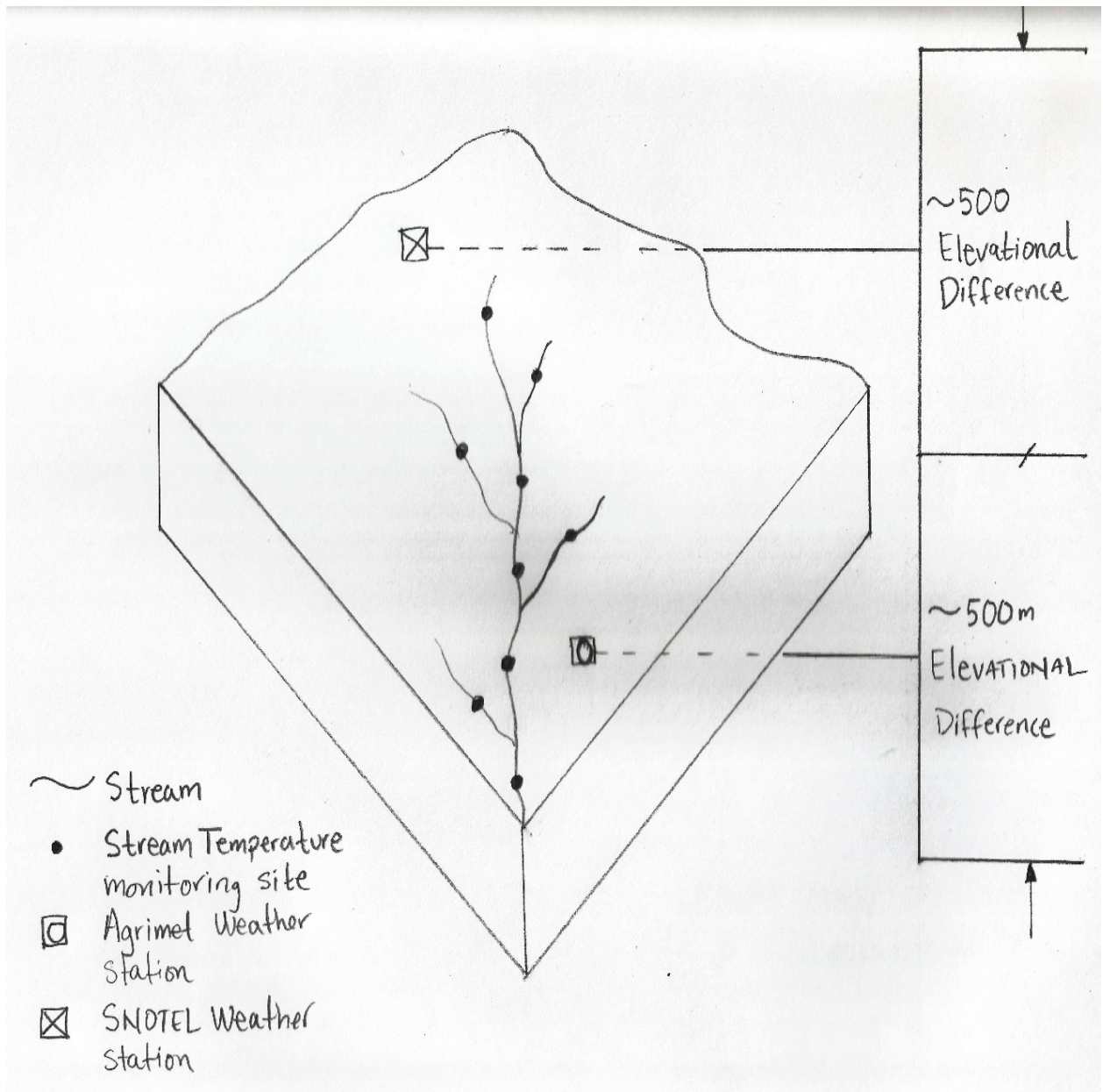


Figure 5: Elevational Difference. Stream temperature monitoring sites with respect to air temperature weather temperature data stations.

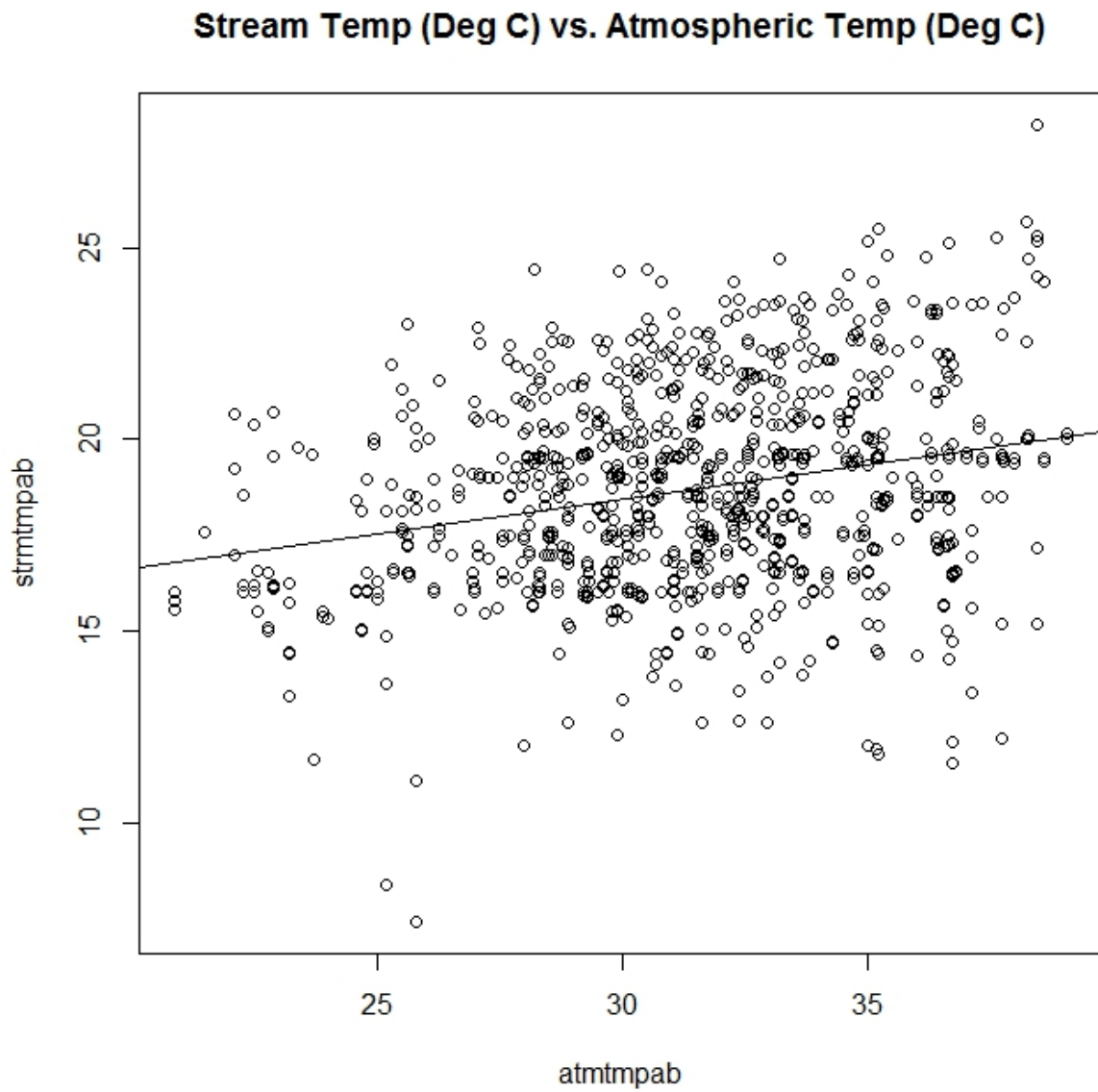


Figure 6: Scatterplot of maximum daily stream temperature from stream temperature monitoring sites and maximum daily air temperature. On the Y axis is the dependent variable maximum daily stream temperature. On the X axis is the independent variable maximum daily air temperature.

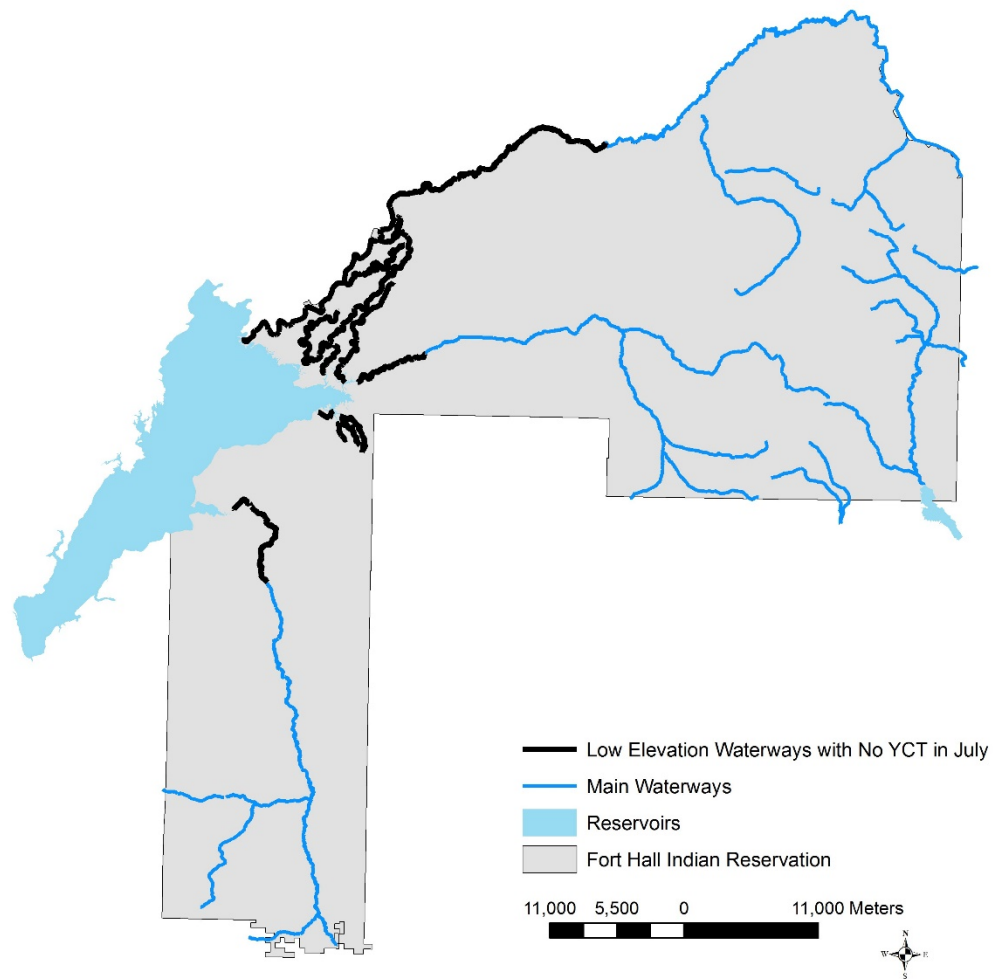


Figure 7: Main waterways of the Fort Hall Indian reservation displaying low elevation streams with no YCT in July in black line segments.

RESULTS

Stream Temperature Model and Future Predictions

To estimate risk of morbidity and mortality to YCT on the FHIR, a robust estimate of stream temperatures was integral. The data obtained from the FHIR WRD were not sufficiently complete to conduct the risk assessment. Although air temperature and elevation both influence stream temperature, air temperature is the most important (Sahoo, Schladow and Reuter 2009). The scatterplot of paired available data shows an apparent relationship between stream and air temperature (Figure 8). Therefore, to show influence of air temperature on stream temperature, a SLRM (Morrill, et al. 2005) regressing stream temperature on air temperature from two different elevations was developed.

This model resulted in an R^2 value of 0.062 and a p-value of <0.0001 . A 95% confidence interval for β_0 was (0.13, 0.23) and β_1 was (11.56, 14.45) (Table 2). The very small p-value of the overall model supports that there is a relationship between maximum daily July stream and air temperatures on the FHIR. The 95% confidence intervals for β_0 and β_1 estimate the value of the true slope and intercept of the SLR model. With this model, maximum daily July stream temperatures were predicted for each of the 59 stream temperature monitoring sites within the FHIR.

The maximum daily July stream temperature predictions resulted in a bolstered dataset that contained 70,122 data points from 59 unique stream temperature monitoring

sites for the current, +50 year, and +100 year time frames. With the completed data set, a deterministic and probabilistic risk assessment was completed.

Deterministic Risk Assessment

For the current time frame, the chosen methodology resulted in 24% of the monitoring stations measured displaying optimal temperature ranges of 5.5 – 16.99°C, or low risk streams for YCT. Of the stations, 57% displayed morbidity temperature ranges of 17 – 20.99°C, or medium risk streams for YCT. Also, of the stations, 19% displayed mortality temperatures of $\geq 21^{\circ}\text{C}$, or high risk streams for YCT (Figure 9, Table 3).

For the +50 year time frame, this methodology resulted in 19% of the stations displaying optimal temperature ranges of 5.5 – 16.99°C, or low risk streams for YCT which is a 5% loss from the current time frame of optimal stream habitat for YCT in the FHIR. Of the stations, 57% displayed morbidity temperature ranges of 17 – 20.99°C, or medium risk streams for YCT. Also, of the stations, 24% displayed mortality temperatures of $\geq 21^{\circ}\text{C}$, or high risk streams for YCT, which is an increase of 5% from the current time frame in high risk streams for YCT on the FHIR (Figure 10, Table 4).

For the +100 year time frame, this methodology resulted in 6% of the stations displaying optimal temperature ranges of 5.5 – 16.99°C, or low risk streams for YCT which is an 18% loss from the current time frame of optimal stream habitat in for YCT in the FHIR. Of the stations, 53% displayed morbidity temperature ranges of 17 – 20.99 °C, or medium risk streams for YCT which is a 4% decrease from the current time frame in medium risk streams for YCT. Also, of the stations, 40% displayed mortality

temperatures of $\geq 21^{\circ}\text{C}$, or high risk streams for YCT which is a 21% increase from the current time frame of high risk YCT habitat on the FHIR (Figure 11, Table 5).

Probabilistic Risk Assessment

Morbidity

For the current time frame, the MCA methodology resulted in 37% of the stream temperature monitoring stations in the FHIR being at or exceeding YCT's morbidity threshold ($17 - 20.99^{\circ}\text{C}$) 0 – 19.99% of the time in July. Ten percent of the stream temperature monitoring stations exceed the threshold 20 – 39.99% of the time in July. Fourteen percent of the stations exceed the threshold 40 – 59.99% of the time in July. Fourteen percent of the stations exceed the threshold 60 – 79.99% of the time and 25% of the stations currently exceed the morbidity threshold 80 – 99.99% of the time in July (Figure 12, Table 6).

For the +50 year time frame, the chosen methodology resulted in the expectation that 37% of the stations will likely exceed the morbidity threshold 0 – 19.99% of the time in July. Five percent of the stations in the FHIR are expected to exceed the morbidity threshold 20 – 39.99% of the time in July, which is a decrease of five percent from the current time frame. Twenty seven percent of the stations will likely exceed the morbidity threshold 40 – 79.99% of the time in July. Thirty percent of the stations in the FHIR can be expected to exceed the morbidity threshold 80 – 99.99% of the time in July, which is a five percent increase from the current time frame (Figure 13, Table 7).

For the +100 year time frame, the chosen MCA methodology resulted in the expectation that 29% of the stations will likely exceed YCT's morbidity threshold 0 – 19.99% of the time in July, which is an 8.5% decrease from the current time frame. Eight and a half percent of the stations are expected to exceed the morbidity threshold 20 – 39.99% of the time in July which is a 2.5% decrease from the current time frame. Five percent of the stations will likely exceed the morbidity threshold 40 – 59.99% of the time in July which is an 8.5% decrease from the current time frame. Thirteen and a half percent of the stations are projected to exceed the morbidity threshold 60 – 79.99% of the time in July. Forty four percent of the stations can be expected to exceed the morbidity threshold 80 – 99.99% of the time in July, which is a 19% increase from the current time frame (Figure 14, Table 8).

Mortality

For the current time frame, the MCA methodology resulted in 81.4% of the stream temperature monitoring stations in the FHIR being at or exceed YCT's mortality threshold ($\geq 21^{\circ}\text{C}$) 0 – 19.99% of the time in July, with most of those stations being below 4%. Five percent of the stations are at or exceed the mortality threshold 20 – 39.99% of the time in July. Five percent of the stations are at or exceed the mortality threshold 40 – 59.99% of the time in July. Eight and a half percent of the stations are at or exceed the mortality threshold 60 – 79.99% of the time in July. One and three quarter percent of the stations are at or exceed the mortality threshold 80 – 99.99% of the time in July in (Figure 14, Table 9).

For the +50 year time frame, the chosen methodology resulted in 74.58% of the stations being at or exceeding YCT's mortality threshold ($\geq 21^{\circ}\text{C}$) 0 – 19.99% of the time in July, which is a 6.8% decrease from the current time frame. About seven percent of the stations can be expected to be at or exceed the mortality threshold 20 – 39.99% of the time in July, which is an increase of 1.7% from the current time frame. Five percent of the stations are likely to be at or exceed the mortality threshold 40 – 59.99% of the time in July. About five percent of the stations are expected to be at or exceed the mortality threshold 60 – 79.99% of the time in July. Eight and a half percent of the stations are expected to be at or exceed the mortality threshold 80 – 99.99% of the time in July, which is a 6.8% increase from the current time frame (Figure 15, Table 10).

For the +100 year time frame, the chosen methodology resulted in 61% of the stream temperature monitoring stations in the FHIR will likely be at or exceed YCT's mortality threshold ($\geq 21^{\circ}\text{C}$) 0 – 19.99% of the time in July, which is a 20% decrease from the current time frame. About five percent of the stations can be expected to be at or exceed the mortality threshold 20 – 39.99% of the time in July. About three percent of the stations will likely be at or exceed the mortality threshold 40 – 59.99% of the time in July which is a 2% decrease from the current time frame. Five percent of the stations are expected to be at or exceed the mortality threshold 60 – 79.99% of the time in July. Twenty five percent of the stations can be expected to be at or exceed the mortality threshold 80 – 99.99% of the time in July, which is a 23.3% increase from the current time frame (Figure 16, Table 11).

Discussion

The results of this study indicate that a substantial amount of suitable YCT habitat within the FHIR will likely be lost due to increased stream temperatures, a direct result of global climate change. At this local scale the bulk of the habitat loss can be expected in the lower elevation areas of the FHIR. Mid to high elevation areas will also be negatively affected but not as much as the lower elevation areas.

The current deterministic risk assessment, which relies on the yearly maximum average July stream temperatures, shows that of the streams monitored in the FHIR, YCT are at risk of temperature related mortality in about 19%, risk of morbidity in about 57%, and of the locations are at optimal conditions in 24%. The +50 year deterministic risk assessment predicts a 5% increase in mortality risk in low elevations and a 5% loss of optimal stream habitat in mid to higher elevations. The +100 year prediction increases high risk to 21% for low elevations and a 17% loss in mid to high elevations (Tables 12 and 13).

The +50 year probabilistic risk assessment predicts a 5% increase in streams that will exceed YCT's morbidity threshold 80 – 99.99% of the time in July and a 7% increase in streams that will exceed YCT mortality 80 – 99.99% of the time in July. The +100 year probabilistic risk assessment predicts a 19% increase in streams that will exceed YCT's morbidity threshold 80 – 99.99% and a 24% increase in streams that will exceed YCT mortality 80-99.99% of the time in July. (Tables 14, 15,16, 17).

Results of the deterministic risk assessment are reasonable estimates of what to expect in the coming years for YCT's morbidity and mortality risks. Because YCT are

not found at elevations below 1460 m (Thurrow and King 1994), focus of the results can be made in stream reaches that are higher than this elevation. The results of the probabilistic approach are similar to the deterministic in that both predict an overall decline of suitable YCT habitat in the coming 100 years.

As with any ecological modeling approach, certain limitations and uncertainties exist within this study. Because of the geographical placement of stream temperature sampling locations, and the timing that measurements were taken, spatial and temporal autocorrelation may be present within the provided data. Generally, autocorrelation is a property of ecological variables and, indeed, of all variables across geographic space (spatial autocorrelation) or observed along time series (temporal autocorrelation) (Legendre et al, 1993). This becomes a problem because the values at neighboring points can be at least partly predicted by the value at any one locality throughout time, these values are not stochastically independent from one another (Legendre 1993). Based on possible autocorrelation within the provided data, key assumptions of independence may in fact be violated. The degree to which the assumption is violated, however, is not known.

Based on this analysis, a majority of the stream locations are already above the morbidity threshold (Figure 5). And many studies of mountainous stream networks within this region suggest this is indeed the case (Isaak, et al. 2010). The expected, continual changes in climate suggest a difficult future for native trout within the FHIR. Drought is expected to intensify, stream-scouring winter floods are likely to become more common in lower-elevation areas, wildfires will be more frequent and severe, and

temperatures will increase in streams. Native trout are already reduced and isolated in many locations, and climate change will exacerbate existing stressors. Some high-elevation areas of the ecosystem, will provide a critical refuge as low-elevation streams and rivers warm and lose base flows. If native trout are to continue to inhabit the waters of this region, a new commitment to watershed protection and restoration will be required for the conservation agenda. The Greater Yellowstone Ecosystem provides much habitat for YCT. Because the FHIR is one of the two Indian reservations within the boundaries of the Greater Yellowstone Ecosystem, unique adaptive management responsibilities and opportunities on tribal land should be explored.

As an example, from the assessment, a specific location of increased risk of morbidity is the FHIR's Cold Creek. Model results show that at this location, the probability of being exceeding the morbidity temperature threshold increases from 34% in the current time frame to 41% in the +50 year time frame to 61% in the +100 year time frame. This being the case, a number of studies show that to decrease stream temperatures and risk of morbidity, adaptive management strategies that could take place may include such activities as bank stabilization, reduce sediment load, and increased shading (Varley and Gresswell 1988; J. Williams, et al. 2009).

Conclusions

Long has it been foretold and prophesized by American Indian elders of past and present that "Great change is coming to the land." As a child I can remember hearing my elders talk amongst themselves around fireplaces in our ceremonial lodges about how

“Our white brother’s way of life is going to lead our world into chaos and despair. We must hold on to our sweet grass and pray to our creator to protect us as indigenous people, for there is going to become a time when the world is going to be in peril and all were going to be able to depend upon is prayer.” I feel that that time is fast approaching; yet hope remains.

The members of the FHIR have an inherently close and spiritual bond to the waterways and their native YCT. Within and around the GYE and the FHIR is where these great nations of people continue to hunt, fish, and thrive as modernized indigenous peoples. The GYE provides much habitat for YCT. Because the FHIR is one of the two Indian reservations within the boundaries of the GYE, unique management responsibilities and opportunities on tribal land should be explored. Ultimately, the health of the subsistence based cultures and other communities within the FHIR depends a great deal on the well-being of the waterways and the YCT that have sustained their lives for generations.

Climate change is happening now and faster than ever (IPCC 2013). Can this be a part of what it was that my elderly people were talking about? I am certain that it is. And it is very evident within the FHIR. Changes in climate are occurring on a global scale and the FHIR is not invulnerable. As a result, stream temperature increases are also occurring putting resident YCT at higher risk for temperature related morbidity and mortality. Although this region has experienced periods of warming and cooling in the past, the recent warming trend is unique in its rate and magnitude, and its correlation to greenhouse gas emissions (IPCC 2013). An extraordinary example of how climate

change is expected to affect the rivers and trout of the GYE in the future was the summer of 2007. July of that year was the hottest ever recorded in many locations, causing fishing closures on rivers such as the Jefferson, Madison, Yellowstone, and others (Jackson Hole News and Guide 2007). In Yellowstone, hundreds of trout in the Firehole River perished due to stream temperatures that reached an unprecedented 28°C (Jackson Hole News and Guide 2007). Unfortunately, these types of events are likely to become more common.

Looking through the lens of climate change, this effort led to the understanding that stream temperatures for the current time frame have been increasing as a result of climate change. With the projected increases in future July stream temperatures the optimal habitat for YCT will be significantly diminished as well. Therefore, this study may serve as a call to action to all interested parties within the FHIR, State of Idaho, and the GYE. With the gleaned information and understanding of how stream temperatures will put YCT at higher risk of temperature related morbidity and mortality, it is up to the risk managers of the greater FHIR and the FHIR to take whatever action they deem necessary in their unique environmental management responsibilities.

Table 2: Simple linear regression model results. Regression of observed maximum daily stream temperatures on observed maximum daily air temperatures.

Model Results				
	Estimate	Standard Error	t-value	p-value
β_0	13.00625	0.73442	17.709	< 2e-16
β_1	0.18096	0.02322	7.792	1.76E-14

Residual standard error: 2.584 on 926 degrees of freedom

Multiple R-squared: 0.06154, Adjusted R-squared: 0.06052

F-statistic: 60.72 on 1 and 926 DF, p-value: 1.764e-14

Table 3: Current time frames deterministic risk results.

Stream Temperature Monitoring Site	Elevation (meters)	Yearly Weekly Maximum Average July Stream Temperature	Risk Level
Bakers Creek	1701	16.09	Low
Bannock Creek (Lower)	1334	20.52	High
Bannock Creek (Middle)	1342	19.93	Medium
Bannock Creek (Upper)	1517	18.57	Medium
Bannock Creek (West Fork)	1521	18.47	Medium
Big Jimmy Creek (Bottoms)	1331	20.91	High
Blackfoot River (Just Bridge)	1400	18.96	Medium
Blackfoot River (Morgan Bridge)	1754	15.64	Low
Blackfoot River (Rich Lane Bridge)	1387	19.06	Medium
Blackfoot River (Riverton Bridge)	1350	19.35	Medium
Blackfoot River (Schilling Bridge)	1370	19.25	Medium
Clear Creek	1336	20.42	Medium
Clear Creek (Lower)	1330	21.49	High
Clear Creek (Upper)	1710	15.91	Low
Cold Creek	1533	18.38	Medium
Deadman Creek	1783	15.46	Low
Diggie Creek	1345	19.74	Medium
East Mill Creek -1	1626	16.99	Medium
Jeff Cabin Creek (Bottoms)	1341	20.03	Medium
Jeff Cabin Creek (NSB)	1697	16.27	Low
Jeff Cabin Creek (Putnam)	1757	15.55	Low
Jimmy Drinks East	1330	21.39	High

Table # 3 Continued

Jimmy Drinks West	1332	20.81	High
Kinney Creek	1330	21.30	High
Lincoln Creek	1439	18.77	Medium
Little Toponce Creek	1956	15.37	Low
Moonshine Creek (Upper)	1594	18.09	Medium
Mud Slough	1344	19.84	Medium
Portneuf (Above CR)	1649	16.81	Medium
Portneuf (by Lone Pine Rd)	1697	16.18	Low
Portneuf (Tyhee Gage Station)	1332	20.61	High
Portneuf (Upper)	1752	15.73	Low
Rass Creek	1668	16.45	Low
Rattlesnake (Lower)	1437	18.86	Medium
Rattlesnake (Upper)	1450	18.67	Medium
Red Rock Creek	1730	15.82	Low
Ross Fork (Lower)	1336	20.13	Medium
Ross Fork (Middle)	1377	19.16	Medium
Ross Fork (North-1)	1549	18.28	Medium
Ross Fork (North-2)	1654	16.72	Medium
Ross Fork (South-1)	1562	18.18	Medium
Ross Fork (South-2)	1623	17.17	Medium
SC Cable Bridge	1330	21.20	High
SC USGS	1336	20.32	Medium
Spring Creek (Broncho Bridge)	1345	19.64	Medium
Spring Creek (Sheepskin)	1336	20.23	Medium
Squaw Creek	1665	16.54	Medium
SR Neely	1297	21.59	High
SR south of Blackfoot	1345	19.54	Medium
SR Tilden Bridge	1345	19.45	Medium
Thirty Day Creek-1	1623	17.08	Medium
Tindaha Springs	1332	20.71	High
Toponce Creek (North Fork)	2020	15.28	Low
Trail Creek	1703	16.00	Low
UMPR	1678	16.36	Low
Warm Springs	1660	16.63	Medium
Wide Creek	1330	21.10	High
Wood Creek	1642	16.90	Medium

Table 4: +50 year times frames deterministic risk results.

Stream Temperature Monitoring Site	Elevation (meters)	Yearly Weekly Maximum Average July Stream Temperature	Plus 50 Year Time Frame Risk Level
Bakers Creek	1701	16.33	Low
Bannock Creek (Lower)	1334	20.86	High
Bannock Creek (Middle)	1342	20.26	Medium
Bannock Creek (Upper)	1517	18.86	Medium
Bannock Creek (West Fork)	1521	18.76	Medium
Big Jimmy Creek (Bottoms)	1331	21.25	High
Blackfoot River (Just Bridge)	1400	19.26	Medium
Blackfoot River (Morgan Bridge)	1754	15.87	Low
Blackfoot River (Rich Lane Bridge)	1387	19.36	Medium
Blackfoot River (Riverton Bridge)	1350	19.66	Medium
Blackfoot River (Schilling Bridge)	1370	19.56	Medium
Clear Creek	1336	20.76	High
Clear Creek (Lower)	1330	21.85	High
Clear Creek (Upper)	1710	16.15	Low
Cold Creek	1533	18.66	Medium
Deadman Creek	1783	15.69	Low
Diggie Creek	1345	20.06	Medium
East Mill Creek -1	1626	17.26	Medium
Jeff Cabin Creek (Bottoms)	1341	20.36	Medium
Jeff Cabin Creek (NSB)	1697	16.52	Medium
Jeff Cabin Creek (Putnam)	1757	15.78	Low
Jimmy Drinks East	1330	21.75	High
Jimmy Drinks West	1332	21.15	High
Kinney Creek	1330	21.65	High
Lincoln Creek	1439	19.06	Medium
Little Toponce Creek	1956	15.60	Low
Moonshine Creek (Upper)	1594	18.36	Medium
Mud Slough	1344	20.16	Medium
Portneuf (Above CR)	1649	17.07	Medium
Portneuf (by Lone Pine Rd)	1697	16.43	Low
Portneuf (Tyhee Gage Station)	1332	20.96	High
Portneuf (Upper)	1752	15.96	Low
Rass Creek	1668	16.70	Medium
Rattlesnake (Lower)	1437	19.16	Medium

Table #4 Continued

Rattlesnake (Upper)	1450	18.96	Medium
Red Rock Creek	1730	16.06	Low
Ross Fork (Lower)	1336	20.46	Medium
Ross Fork (Middle)	1377	19.46	Medium
Ross Fork (North-1)	1549	18.56	Medium
Ross Fork (North-2)	1654	16.98	Medium
Ross Fork (South-1)	1562	18.46	Medium
Ross Fork (South-2)	1623	17.44	Medium
SC Cable Bridge	1330	21.55	High
SC USGS	1336	20.66	High
Spring Creek (Broncho Bridge)	1345	19.96	Medium
Spring Creek (Sheepskin)	1336	20.56	High
Squaw Creek	1665	16.80	Medium
SR Neely	1297	21.95	High
SR south of Blackfoot	1345	19.86	Medium
SR Tilden Bridge	1345	19.76	Medium
Thirty Day Creek-1	1623	17.35	Medium
Tindaha Springs	1332	21.05	High
Toponce Creek (North Fork)	2020	15.50	Low
Trail Creek	1703	16.24	Low
UMPR	1678	16.61	Medium
Warm Springs	1660	16.89	Medium
Wide Creek	1330	21.45	High
Wood Creek	1642	17.16	Medium

Table 5: +100 year time frames deterministic risk results

Stream Temperature Monitoring Site	Elevation (meters)	Yearly Weekly Maximum Average July Stream Temperature	Plus 50 Year Time Frame Risk Level
Bakers Creek	1701	17.01	Medium
Bannock Creek (Lower)	1334	21.78	High
Bannock Creek (Middle)	1342	21.15	High
Bannock Creek (Upper)	1517	19.65	Medium
Bannock Creek (West Fork)	1521	19.55	Medium
Big Jimmy Creek (Bottoms)	1331	22.21	High
Blackfoot River (Just Bridge)	1400	20.08	Medium
Blackfoot River (Morgan Bridge)	1754	16.51	Medium
Blackfoot River (Rich Lane Bridge)	1387	20.19	Medium
Blackfoot River (Riverton Bridge)	1350	20.51	High
Blackfoot River (Schilling Bridge)	1370	20.40	Medium
Clear Creek	1336	21.68	High
Clear Creek (Lower)	1330	22.85	High
Clear Creek (Upper)	1710	16.81	Medium
Cold Creek	1533	19.44	Medium
Deadman Creek	1783	16.31	Low
Diggie Creek	1345	20.93	High
East Mill Creek -1	1626	18.00	Medium
Jeff Cabin Creek (Bottoms)	1341	21.25	High
Jeff Cabin Creek (NSB)	1697	17.20	Medium
Jeff Cabin Creek (Putnam)	1757	16.41	Low
Jimmy Drinks East	1330	22.74	High
Jimmy Drinks West	1332	22.10	High
Kinney Creek	1330	22.64	High
Lincoln Creek	1439	19.87	Medium
Little Toponce Creek	1956	16.21	Low
Moonshine Creek (Upper)	1594	19.12	Medium
Mud Slough	1344	21.04	High
Portneuf (Above CR)	1649	17.80	Medium
Portneuf (by Lone Pine Rd)	1697	17.10	Medium

Table #5 Continued

Portneuf (Tyhee Gage Station)	1332	21.89	High
Portneuf (Upper)	1752	16.61	Medium
Rass Creek	1668	17.40	Medium
Rattlesnake (Lower)	1437	19.97	Medium
Rattlesnake (Upper)	1450	19.76	Medium
Red Rock Creek	1730	16.71	Medium
Ross Fork (Lower)	1336	21.36	High
Ross Fork (Middle)	1377	20.29	Medium
Ross Fork (North-1)	1549	19.33	Medium
Ross Fork (North-2)	1654	17.70	Medium
Ross Fork (South-1)	1562	19.23	Medium
Ross Fork (South-2)	1623	18.19	Medium
SC Cable Bridge	1330	22.53	High
SC USGS	1336	21.57	High
Spring Creek (Broncho Bridge)	1345	20.83	High
Spring Creek (Sheepskin)	1336	21.47	High
Squaw Creek	1665	17.50	Medium
SR Neely	1297	22.96	High
SR south of Blackfoot	1345	20.72	High
SR Tilden Bridge	1345	20.61	High
Thirty Day Creek-1	1623	18.10	Medium
Tindaha Springs	1332	22.00	High
Toponce Creek (North Fork)	2020	16.11	Low
Trail Creek	1703	16.91	Medium
UMPR	1678	17.30	Medium
Warm Springs	1660	17.60	Medium
Wide Creek	1330	22.42	High
Wood Creek	1642	17.90	Medium

Table 6: Probabilistic Risk Assessment: Morbidity. Current Time Frame: Percent of Time in July YCT Morbidity Thermal Threshold is Exceeded

Probabilistic Risk Assessment: Morbidity		
Stream Temperature Monitoring Site	Elevation (meters)	Current Time Frame: Percent of Time in July YCT Morbidity Thermal Threshold is Exceeded
Bakers Creek	1701	0.0
Bannock Creek (Lower)	1334	86.4
Bannock Creek (Middle)	1342	73.6
Bannock Creek (Upper)	1517	39.0
Bannock Creek (West Fork)	1521	36.7
Big Jimmy Creek (Bottoms)	1331	93.0
Blackfoot River (Just Bridge)	1400	49.1
Blackfoot River (Morgan Bridge)	1754	0.0
Blackfoot River (Rich Lane Bridge)	1387	51.9
Blackfoot River (Riverton Bridge)	1350	59.1
Blackfoot River (Schilling Bridge)	1370	56.5
Clear Creek	1336	84.7
Clear Creek (Lower)	1330	98.4
Clear Creek (Upper)	1710	0.0
Cold Creek	1533	34.3
Deadman Creek	1783	0.0
Diggie Creek	1345	68.5
East Mill Creek -1	1626	3.4
Jeff Cabin Creek (Bottoms)	1341	75.5
Jeff Cabin Creek (NSB)	1697	0.0
Jeff Cabin Creek (Putnam)	1757	0.0
Jimmy Drinks East	1330	97.7
Jimmy Drinks West	1332	91.6
Kinney Creek	1330	97.1
Lincoln Creek	1439	43.9
Little Toponce Creek	1956	0.0
Moonshine Creek (Lower)	1331	94.1
Moonshine Creek (Upper)	1594	27.4
Mud Slough	1344	71.7
Portneuf (Above CR)	1649	1.7
Portneuf (by Lone Pine Rd)	1697	0.0

Table #6 Continued

Portneuf (Tyhee Gage Station)	1332	88.4
Portneuf (Upper)	1752	0.0
Rass Creek	1668	0.1
Rattlesnake (Lower)	1437	46.7
Rattlesnake (Upper)	1450	41.6
Red Rock Creek	1730	0.0
Ross Fork (Lower)	1336	78.1
Ross Fork (Middle)	1377	54.4
Ross Fork (North-1)	1549	32.0
Ross Fork (North-2)	1654	1.1
Ross Fork (South-1)	1562	29.4
Ross Fork (South-2)	1623	6.3
SC Cable Bridge	1330	96.4
SC USGS	1336	82.5
Spring Creek (Broncho Bridge)	1345	65.8
Spring Creek (Sheepskin)	1336	80.1
Squaw Creek	1665	0.4
SR Neely	1297	98.7
SR south of Blackfoot	1345	64.5
SR Tilden Bridge	1345	61.3
Thirty Day Creek-1	1623	4.7
Tindaha Springs	1332	90.2
Toponce Creek (North Fork)	2020	0.0
Trail Creek	1703	0.0
UMPR	1678	0.1
Warm Springs	1660	0.7
Wide Creek	1330	95.4
Wood Creek	1642	2.6

Table 7: Table: Probabilistic Risk Assessment: Morbidity. +50 Year time frame: Percent of Time in July YCT Morbidity Thermal Threshold is Expected to be Exceeded.

Probabilistic Risk Assessment: Morbidity		
Stream Temperature Monitoring Site	Elevation (meters)	+50 Year Time Frame: Percent of Time in July YCT Morbidity Thermal Threshold is Expected to be Exceeded
Bakers Creek	1701	0.0
Bannock Creek (Lower)	1334	92.5
Bannock Creek (Middle)	1342	81.1
Bannock Creek (Upper)	1517	47.0
Bannock Creek (West Fork)	1521	44.1
Big Jimmy Creek (Bottoms)	1331	96.9
Blackfoot River (Just Bridge)	1400	56.6
Blackfoot River (Morgan Bridge)	1754	0.0
Blackfoot River (Rich Lane Bridge)	1387	58.9
Blackfoot River (Riverton Bridge)	1350	65.9
Blackfoot River (Schilling Bridge)	1370	63.8
Clear Creek	1336	91.2
Clear Creek (Lower)	1330	99.5
Clear Creek (Upper)	1710	0.0
Cold Creek	1533	41.6
Deadman Creek	1783	0.0
Diggie Creek	1345	76.3
East Mill Creek -1	1626	8.1
Jeff Cabin Creek (Bottoms)	1341	83.4
Jeff Cabin Creek (NSB)	1697	0.3
Jeff Cabin Creek (Putnam)	1757	0.0
Jimmy Drinks East	1330	99.3
Jimmy Drinks West	1332	96.2
Kinney Creek	1330	99.1
Lincoln Creek	1439	51.6
Little Toponce Creek	1956	0.0
Moonshine Creek (Lower)	1331	97.7
Moonshine Creek (Upper)	1594	34.2
Mud Slough	1344	78.8
Portneuf (Above CR)	1649	4.6

Table #7 Continued

Portneuf (by Lone Pine Rd)	1697	0.1
Portneuf (Tyhee Gage Station)	1332	93.9
Portneuf (Upper)	1752	0.0
Rass Creek	1668	0.9
Rattlesnake (Lower)	1437	53.7
Rattlesnake (Upper)	1450	49.1
Red Rock Creek	1730	0.0
Ross Fork (Lower)	1336	85.3
Ross Fork (Middle)	1377	61.9
Ross Fork (North-1)	1549	39.3
Ross Fork (North-2)	1654	3.5
Ross Fork (South-1)	1562	36.4
Ross Fork (South-2)	1623	11.6
SC Cable Bridge	1330	98.7
SC USGS	1336	89.3
Spring Creek (Broncho Bridge)	1345	74.1
Spring Creek (Sheepskin)	1336	87.1
Squaw Creek	1665	1.6
SR Neely	1297	99.7
SR south of Blackfoot	1345	71.4
SR Tilden Bridge	1345	68.8
Thirty Day Creek-1	1623	9.8
Tindaha Springs	1332	95.0
Toponce Creek (North Fork)	2020	0.0
Trail Creek	1703	0.0
UMPR	1678	0.6
Warm Springs	1660	2.3
Wide Creek	1330	98.2
Wood Creek	1642	6.2

Table 8: Probabilistic Risk Assessment: Morbidity. +100 Year Time Frame: Percent of time in July YCT morbidity thermal threshold is expected to be exceeded.

Probabilistic Risk Assessment: Morbidity		
Stream Temperature Monitoring Site	Elevation (meters)	+100 Year Time Frame: Percent of Time in July YCT Morbidity Thermal Threshold is Expected to be Exceeded
Bakers Creek	1701	3.4
Bannock Creek (Lower)	1334	99.5
Bannock Creek (Middle)	1342	96.3
Bannock Creek (Upper)	1517	66.5
Bannock Creek (West Fork)	1521	63.6
Big Jimmy Creek (Bottoms)	1331	99.9
Blackfoot River (Just Bridge)	1400	77.2
Blackfoot River (Morgan Bridge)	1754	0.1
Blackfoot River (Rich Lane Bridge)	1387	79.5
Blackfoot River (Riverton Bridge)	1350	86.6
Blackfoot River (Schilling Bridge)	1370	84.1
Clear Creek	1336	99.4
Clear Creek (Lower)	1330	100.0
Clear Creek (Upper)	1710	1.4
Cold Creek	1533	60.9
Deadman Creek	1783	0.0
Diggie Creek	1345	94.0
East Mill Creek -1	1626	25.2
Jeff Cabin Creek (Bottoms)	1341	97.2
Jeff Cabin Creek (NSB)	1697	6.4
Jeff Cabin Creek (Putnam)	1757	0.1
Jimmy Drinks East	1330	100.0
Jimmy Drinks West	1332	99.9
Kinney Creek	1330	100.0
Lincoln Creek	1439	71.4
Little Toponce Creek	1956	0.0
Moonshine Creek (Lower)	1331	100.0
Moonshine Creek (Upper)	1594	53.1
Mud Slough	1344	95.5
Portneuf (Above CR)	1649	20.4
Portneuf (by Lone Pine Rd)	1697	4.9

Table #8 Continued

Portneuf (Tyhee Gage Station)	1332	99.7
Portneuf (Upper)	1752	0.4
Rass Creek	1668	10.6
Rattlesnake (Lower)	1437	74.6
Rattlesnake (Upper)	1450	69.2
Red Rock Creek	1730	0.8
Ross Fork (Lower)	1336	98.1
Ross Fork (Middle)	1377	81.9
Ross Fork (North-1)	1549	58.5
Ross Fork (North-2)	1654	17.7
Ross Fork (South-1)	1562	55.7
Ross Fork (South-2)	1623	29.7
SC Cable Bridge	1330	100.0
SC USGS	1336	98.9
Spring Creek (Broncho Bridge)	1345	92.4
Spring Creek (Sheepskin)	1336	98.5
Squaw Creek	1665	13.0
SR Neely	1297	100.0
SR south of Blackfoot	1345	91.1
SR Tilden Bridge	1345	88.6
Thirty Day Creek-1	1623	27.1
Tindaha Springs	1332	99.8
Toponce Creek (North Fork)	2020	0.0
Trail Creek	1703	2.3
UMPR	1678	8.3
Warm Springs	1660	14.8
Wide Creek	1330	100.0
Wood Creek	1642	22.6

Table 9: Probabilistic Risk Assessment: Mortality. Current Time Frame: Percent of Time in July YCT Mortality Thermal Threshold is Exceeded.

Probabilistic Risk Assessment: Mortality		
Stream Temperature Monitoring Site	Elevation (meters)	Current Time Frame: Percent of Time in July YCT Mortality Thermal Threshold is Exceeded
Bakers Creek	1701	0.0
Bannock Creek (Lower)	1334	19.6
Bannock Creek (Middle)	1342	2.6
Bannock Creek (Upper)	1517	0.0
Bannock Creek (West Fork)	1521	0.0
Big Jimmy Creek (Bottoms)	1331	43.1
Blackfoot River (Just Bridge)	1400	0.0
Blackfoot River (Morgan Bridge)	1754	0.0
Blackfoot River (Rich Lane Bridge)	1387	0.0
Blackfoot River (Riverton Bridge)	1350	0.1
Blackfoot River (Schilling Bridge)	1370	0.1
Clear Creek	1336	15.2
Clear Creek (Lower)	1330	79.3
Clear Creek (Upper)	1710	0.0
Cold Creek	1533	0.0
Deadman Creek	1783	0.0
Diggie Creek	1345	1.0
East Mill Creek -1	1626	0.0
Jeff Cabin Creek (Bottoms)	1341	3.8
Jeff Cabin Creek (NSB)	1697	0.0
Jeff Cabin Creek (Putnam)	1757	0.0
Jimmy Drinks East	1330	74.5
Jimmy Drinks West	1332	36.6
Kinney Creek	1330	68.9
Lincoln Creek	1439	0.0
Little Toponce Creek	1956	0.0
Moonshine Creek (Lower)	1331	49.6
Moonshine Creek (Upper)	1594	0.0
Mud Slough	1344	1.6
Portneuf (Above CR)	1649	0.0
Portneuf (by Lone Pine Rd)	1697	0.0
Portneuf (Tyhee Gage Station)	1332	24.6
Portneuf (Upper)	1752	0.0
Rass Creek	1668	0.0
Rattlesnake (Lower)	1437	0.0

Table #9 Continued

Rattlesnake (Upper)	1450	0.0
Red Rock Creek	1730	0.0
Ross Fork (Lower)	1336	5.8
Ross Fork (Middle)	1377	0.0
Ross Fork (North-1)	1549	0.0
Ross Fork (North-2)	1654	0.0
Ross Fork (South-1)	1562	0.0
Ross Fork (South-2)	1623	0.0
SC Cable Bridge	1330	62.6
SC USGS	1336	10.9
Spring Creek (Broncho Bridge)	1345	0.6
Spring Creek (Sheepskin)	1336	8.2
Squaw Creek	1665	0.0
SR Neely	1297	83.1
SR south of Blackfoot	1345	0.1
SR Tilden Bridge	1345	0.2
Thirty Day Creek-1	1623	0.0
Tindaha Springs	1332	30.4
Toponce Creek (North Fork)	2020	0.0
Trail Creek	1703	0.0
UMPR	1678	0.0
Warm Springs	1660	0.0
Wide Creek	1330	56.2
Wood Creek	1642	0.0

Table 10: Probabilistic Risk Assessment: Mortality. +50 Year time frame: Percent of Time in July YCT Mortality Thermal Threshold is Expected to be Exceeded.

Probabilistic Risk Assessment: Mortality		
Stream Temperature Monitoring Site	Elevation (meters)	+50 Year time frame: Percent of Time in July YCT Mortality Thermal Threshold is Expected to be Exceeded
Bakers Creek	1701	0.0
Bannock Creek (Lower)	1334	39.5
Bannock Creek (Middle)	1342	8.7
Bannock Creek (Upper)	1517	0.0
Bannock Creek (West Fork)	1521	0.0
Big Jimmy Creek (Bottoms)	1331	66.8
Blackfoot River (Just Bridge)	1400	0.0
Blackfoot River (Morgan Bridge)	1754	0.0
Blackfoot River (Rich Lane Bridge)	1387	0.1
Blackfoot River (Riverton Bridge)	1350	0.5
Blackfoot River (Schilling Bridge)	1370	0.3
Clear Creek	1336	32.8
Clear Creek (Lower)	1330	92.7
Clear Creek (Upper)	1710	0.0
Cold Creek	1533	0.0
Deadman Creek	1783	0.0
Diggie Creek	1345	3.8
East Mill Creek -1	1626	0.0
Jeff Cabin Creek (Bottoms)	1341	12.0
Jeff Cabin Creek (NSB)	1697	0.0
Jeff Cabin Creek (Putnam)	1757	0.0
Jimmy Drinks East	1330	89.6
Jimmy Drinks West	1332	59.9
Kinney Creek	1330	86.4
Lincoln Creek	1439	0.0
Little Toponce Creek	1956	0.0
Moonshine Creek (Lower)	1331	72.4
Moonshine Creek (Upper)	1594	0.0
Mud Slough	1344	5.9
Portneuf (Above CR)	1649	0.0
Portneuf (by Lone Pine Rd)	1697	0.0
Portneuf (Tyhee Gage Station)	1332	46.1

Table #10 Continued

Portneuf (Upper)	1752	0.0
Rass Creek	1668	0.0
Rattlesnake (Lower)	1437	0.0
Rattlesnake (Upper)	1450	0.0
Red Rock Creek	1730	0.0
Ross Fork (Lower)	1336	16.1
Ross Fork (Middle)	1377	0.1
Ross Fork (North-1)	1549	0.0
Ross Fork (North-2)	1654	0.0
Ross Fork (South-1)	1562	0.0
Ross Fork (South-2)	1623	0.0
SC Cable Bridge	1330	82.9
SC USGS	1336	26.2
Spring Creek (Broncho Bridge)	1345	2.5
Spring Creek (Sheepskin)	1336	20.4
Squaw Creek	1665	0.0
SR Neely	1297	94.6
SR south of Blackfoot	1345	0.9
SR Tilden Bridge	1345	1.0
Thirty Day Creek-1	1623	0.0
Tindaha Springs	1332	53.0
Toponce Creek (North Fork)	2020	0.0
Trail Creek	1703	0.0
UMPR	1678	0.0
Warm Springs	1660	0.0
Wide Creek	1330	78.0
Wood Creek	1642	0.0

Table 11: Probabilistic Risk Assessment: Mortality. +100 Year time frame: Percent of Time in July YCT Mortality Thermal Threshold is Expected to be Exceeded.

Probabilistic Risk Assessment: Mortality		
Stream Temperature Monitoring Site	Elevation (meters)	+100 Year time frame: Percent of Time in July YCT Mortality Thermal Threshold is Expected to be Exceeded
Bakers Creek	1701	0.0
Bannock Creek (Lower)	1334	91.8
Bannock Creek (Middle)	1342	60.0
Bannock Creek (Upper)	1517	0.1
Bannock Creek (West Fork)	1521	0.0
Big Jimmy Creek (Bottoms)	1331	98.3
Blackfoot River (Just Bridge)	1400	2.2
Blackfoot River (Morgan Bridge)	1754	0.0
Blackfoot River (Rich Lane Bridge)	1387	5.5
Blackfoot River (Riverton Bridge)	1350	16.7
Blackfoot River (Schilling Bridge)	1370	11.8
Clear Creek	1336	88.8
Clear Creek (Lower)	1330	99.9
Clear Creek (Upper)	1710	0.0
Cold Creek	1533	0.0
Deadman Creek	1783	0.0
Diggie Creek	1345	44.6
East Mill Creek -1	1626	0.0
Jeff Cabin Creek (Bottoms)	1341	67.0
Jeff Cabin Creek (NSB)	1697	0.0
Jeff Cabin Creek (Putnam)	1757	0.0
Jimmy Drinks East	1330	99.9
Jimmy Drinks West	1332	97.6
Kinney Creek	1330	99.7
Lincoln Creek	1439	0.7
Little Toponce Creek	1956	0.0
Moonshine Creek (Lower)	1331	99.0
Moonshine Creek (Upper)	1594	0.0
Mud Slough	1344	52.6
Portneuf (Above CR)	1649	0.0
Portneuf (by Lone Pine Rd)	1697	0.0
Portneuf (Tyhee Gage Station)	1332	94.5

Table #11 Continued

Portneuf (Upper)	1752	0.0
Rass Creek	1668	0.0
Rattlesnake (Lower)	1437	1.1
Rattlesnake (Upper)	1450	0.3
Red Rock Creek	1730	0.0
Ross Fork (Lower)	1336	74.2
Ross Fork (Middle)	1377	8.2
Ross Fork (North-1)	1549	0.0
Ross Fork (North-2)	1654	0.0
Ross Fork (South-1)	1562	0.0
Ross Fork (South-2)	1623	0.0
SC Cable Bridge	1330	99.6
SC USGS	1336	85.0
Spring Creek (Broncho Bridge)	1345	36.6
Spring Creek (Sheepskin)	1336	80.2
Squaw Creek	1665	0.0
SR Neely	1297	100.0
SR south of Blackfoot	1345	27.2
SR Tilden Bridge	1345	22.5
Thirty Day Creek-1	1623	0.0
Tindaha Springs	1332	96.3
Toponce Creek (North Fork)	2020	0.0
Trail Creek	1703	0.0
UMPR	1678	0.0
Warm Springs	1660	0.0
Wide Creek	1330	99.4
Wood Creek	1642	0.0

Table 12: Summary table displaying the deterministic risk percentage for each of the time frames in the study.

Percentage of Streams Monitored			
Deterministic Risk Level	Time Frame		
	Current	+50 Year	+100 year
High (Mortality)	18.97	24.14	39.66
Medium (Morbidity)	56.90	56.90	53.45
Low (Optimal)	24.14	18.97	6.90

Table 13: Predicted percent change from current time frame for streams monitored. High risk streams increase while medium and low risk streams decrease.

Predicted Percent Change in Streams Monitored From Current Time Frame		
Deterministic Risk Level	Time Frame	
	+50 Year	+100 year
High (Mortality)	5.17	20.69
Medium (Morbidity)	0.00	-3.45
Low (Optimal)	-5.17	-17.24

Table 14: Probabilistic Risk Assessment: Percent of Streams monitored that Exceed YCT Morbidity Threshold (17 – 20.99°C) for all three time frames in the study.

Probabilistic Risk Assessment: Percent of Streams Monitored that Exceed YCT Morbidity Threshold (17 - 20.99°C)			
Percent of time in July	Time Frame		
	Current	+50 Year	+100 Year
0 - 19.99	37.3	37.3	28.8
20 - 39.99	10.2	5.1	8.5
40 - 59.99	13.6	13.6	5.1
60 -79.99	13.6	13.6	13.6
80 -99.99	25.4	30.5	44.1

Table 15: Predicted Percent Change in Morbidity from Current Time Frame in Streams Monitored. In the future, streams within the FHIR can be expected to exceed YCT's morbidity threshold for significantly greater periods of time.

Predicted Percent Change in Morbidity from Current Time Frame in Streams Monitored		
Percent of time in July	Time Frame	
	+50 Year	+100 Year
0 - 19.99	0.0	-8.5
20 - 39.99	-5.1	-1.7
40 - 59.99	0.0	-8.5
60 -79.99	0.0	0.0
80 -99.99	5.1	18.6

Table 16: Probabilistic Risk Assessment: Percent of Streams monitored that Exceed YCT Mortality Threshold ($\geq 21^{\circ}\text{C}$)

Stations that Exceed YCT Mortality Threshold ($\geq 21^{\circ}\text{C}$)			
Percent of Time in July	Time Frame		
	Current	+50 Year	+100 Year
0 - 19.99	81.4	72.9	61.0
20 - 39.99	5.1	8.5	5.1
40 - 59.99	5.1	5.1	3.4
60 - 79.99	6.8	5.1	5.1
80 - 99.99	1.7	8.5	25.4

Table 17: Predicted Percent Change in Mortality from Current Time Frame in Streams Monitored. In the future, streams within the FHIR can be expected to exceed YCT's mortality threshold for significantly greater periods of time.

Predicted Percent Change in Mortality from Current Time Frame in Streams Monitored		
Percent of time in July	Time Frame	
	+50 Year	+100 Year
0 - 19.99	-8.5	-20.3
20 - 39.99	3.4	0.0
40 - 59.99	0.0	-1.7
60 - 79.99	-1.7	-1.7
80 - 99.99	6.8	23.7

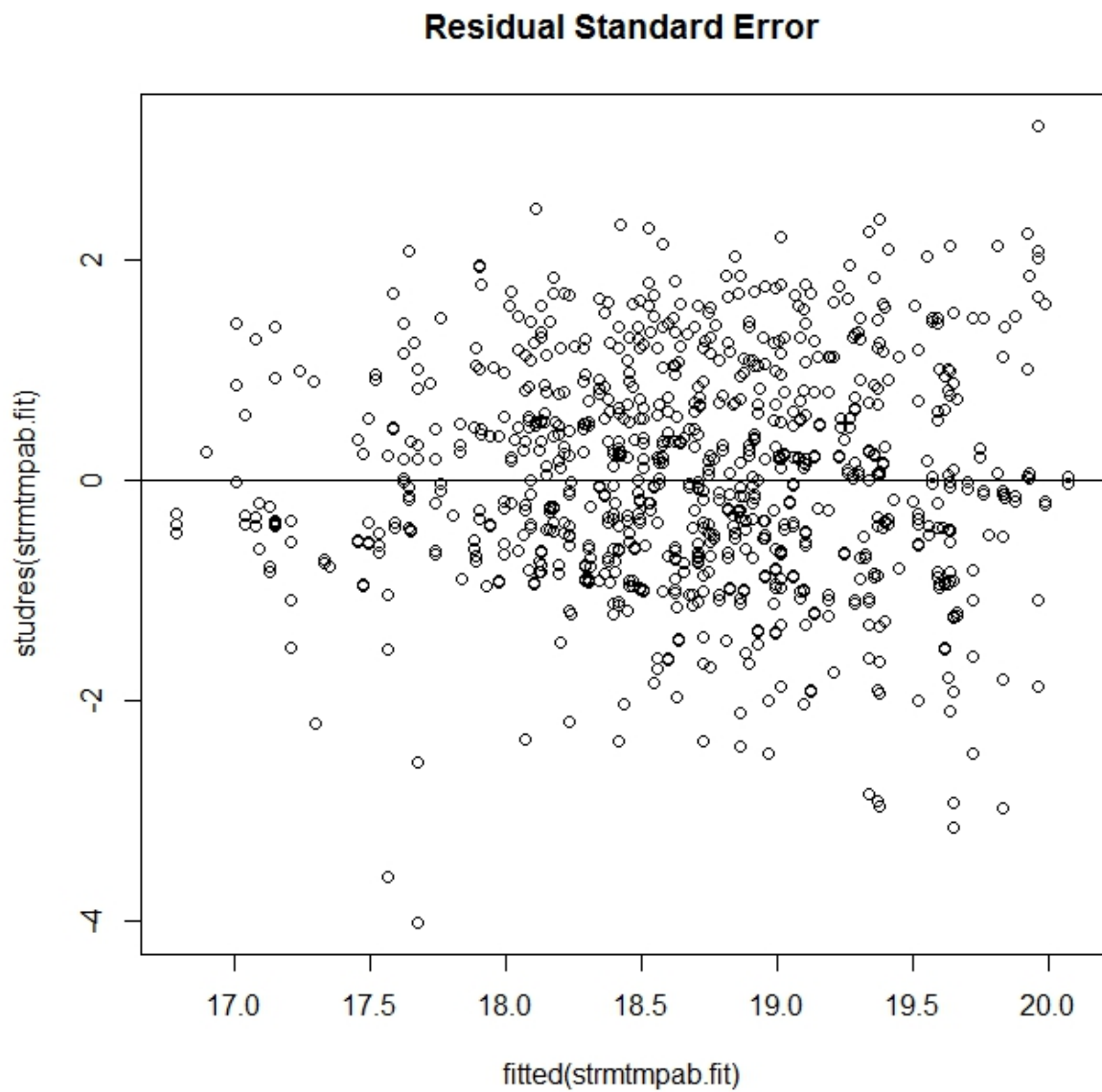


Figure 8: Residual standard error plot assessing the assumption of constant variance for the developed simple linear regression model. Assumption appears to be satisfied.

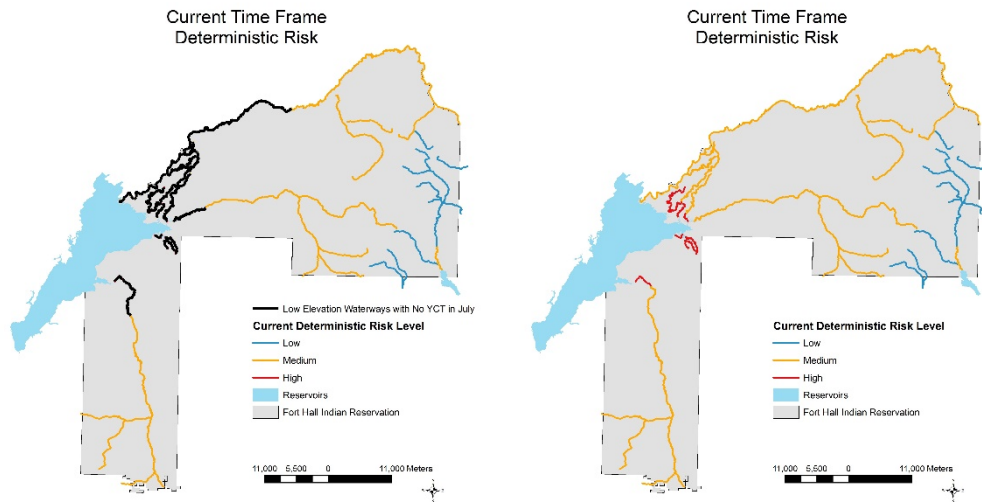


Figure 9: Current time frame deterministic risk. Black line segments represent waterways with no YCT in July. Blue line segments are low or optimal streams for Yellowstone cutthroat trout. Orange line segments are medium risk or streams that exceed YCT morbidity thermal threshold. Red line segments are high risk or streams that exceed YCT mortality thermal threshold.

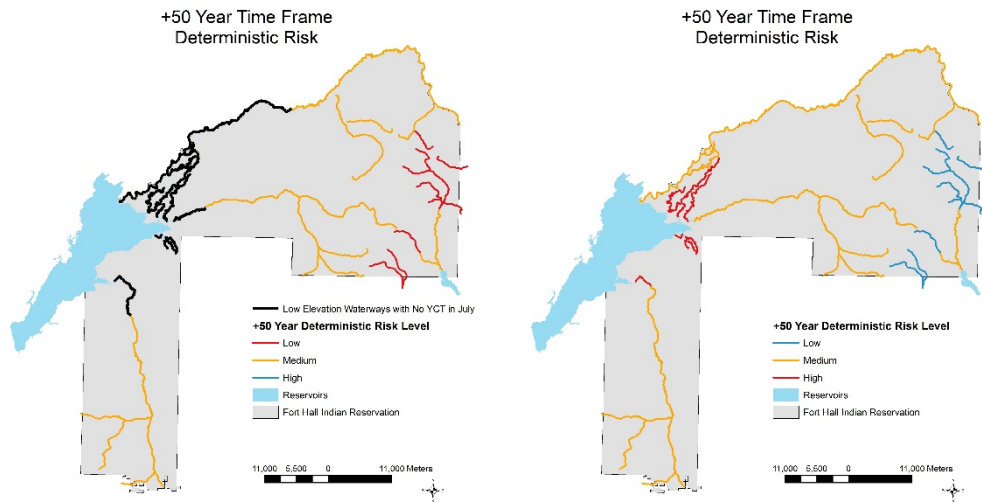


Figure 10: +50 year time frame deterministic risk. Black line segments represent waterways with no YCT in July. Blue line segments are low or optimal streams for Yellowstone cutthroat trout. Orange line segments are medium risk or streams that exceed YCT morbidity thermal threshold. Red line segments are high risk or streams that exceed YCT mortality thermal threshold.

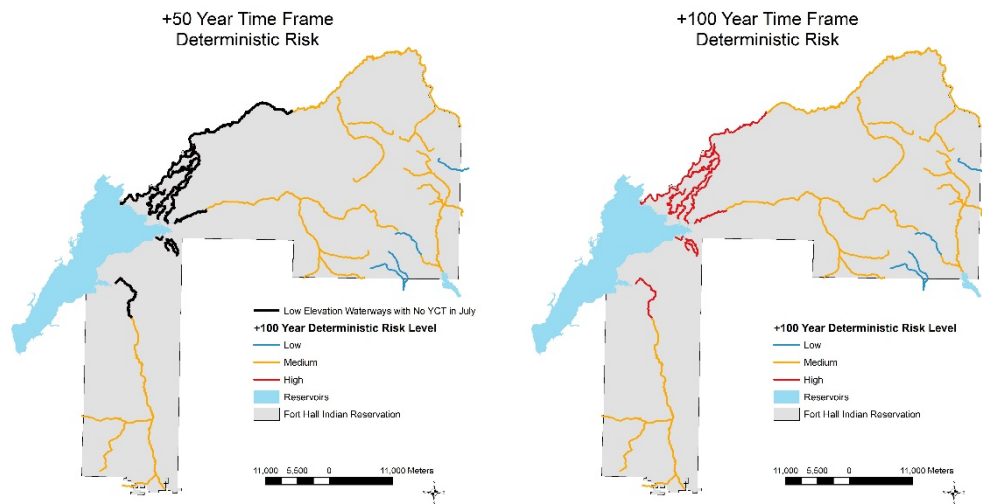


Figure 11: +100 year time frame deterministic risk. Black line segments represent waterways with no YCT in July. Blue line segments are low or optimal streams for Yellowstone cutthroat trout. Orange line segments are medium risk or streams that exceed YCT morbidity thermal threshold. Red line segments are high risk or streams that exceed YCT mortality thermal threshold.

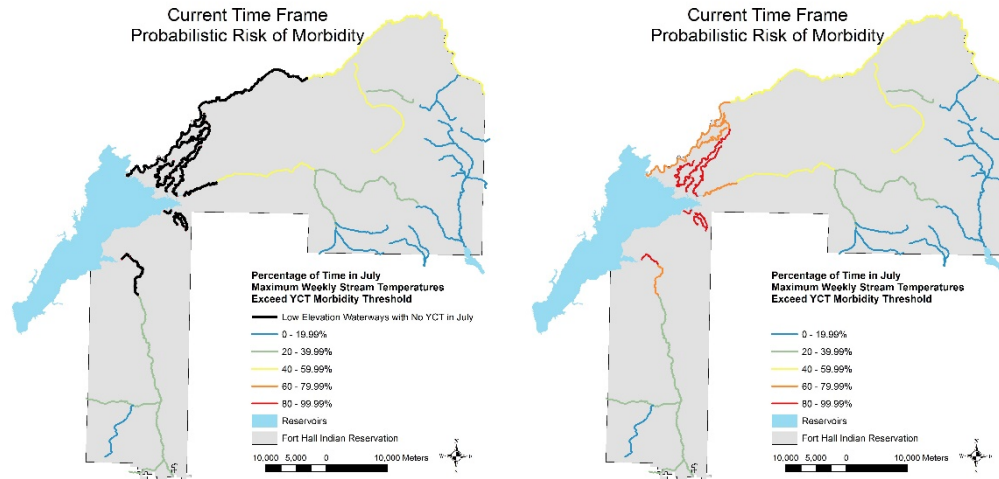


Figure 12: Current time frames probabilistic risk of morbidity. Black line segments represent waterways with no YCT in July. Maps display the percent of time in July in which the weekly average maximum daily stream temperatures exceed YCT's morbidity threshold.

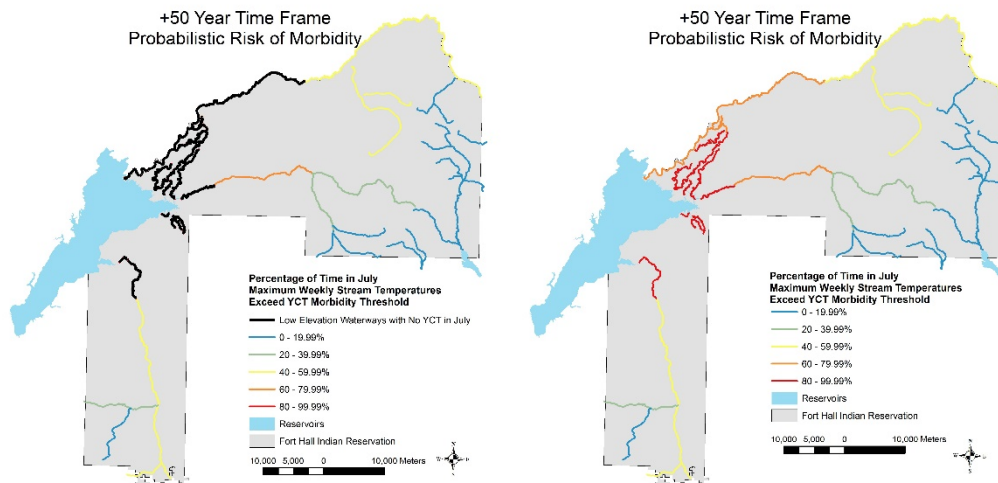


Figure 13: +50 year time frames probabilistic risk of morbidity. Black line segments represent waterways with no YCT in July. Maps display the percent of time in July in which the weekly average maximum daily stream temperatures are expected to exceed YCT's morbidity threshold.

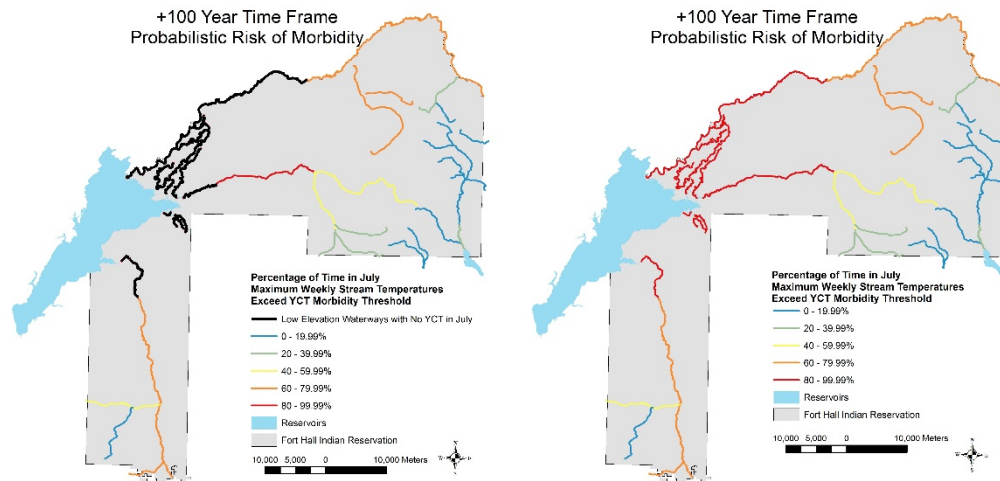


Figure 14: +100 year time frames probabilistic risk of morbidity. Black line segments represent waterways with no YCT in July. Maps display the percent of time in July in which the weekly average maximum daily stream temperatures are expected to exceed YCT's morbidity threshold.

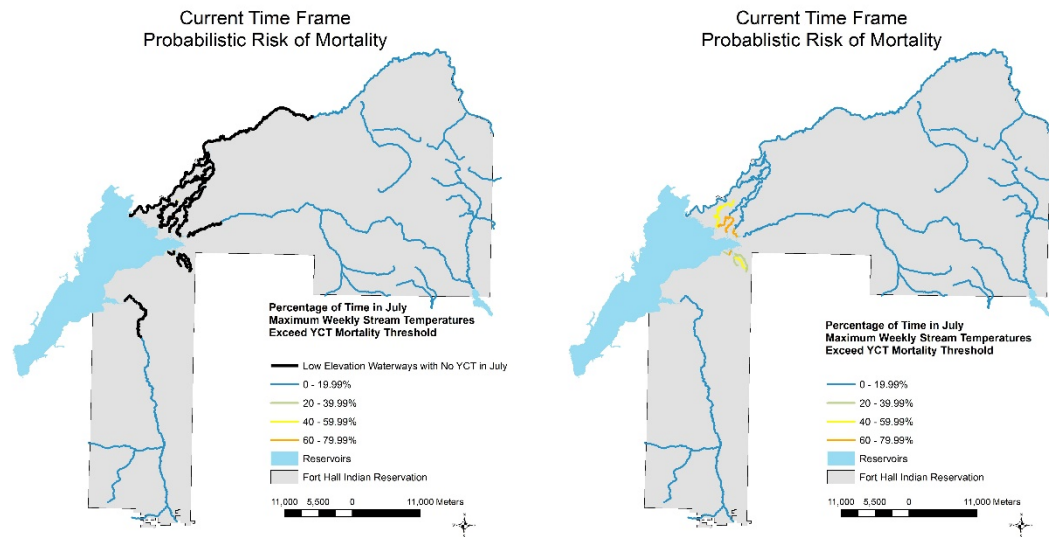


Figure 15: Current time frames probabilistic risk of mortality. Black line segments represent waterways with no YCT in July. Maps display the percent of time in July in which the weekly average maximum daily stream temperatures exceed YCT's mortality threshold.

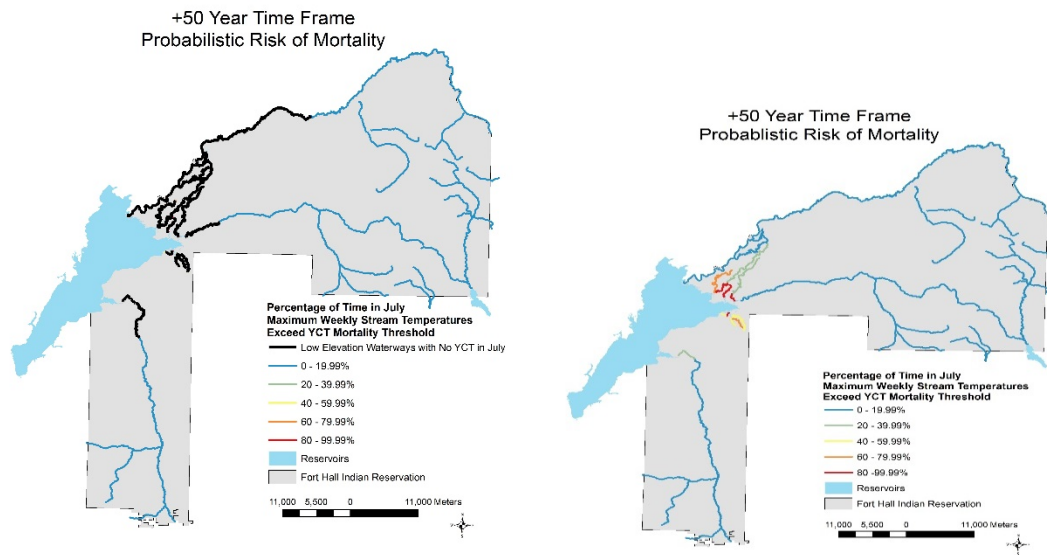


Figure 16: +50 year time frames probabilistic risk of mortality. Black line segments represent waterways with no YCT in July. Maps display the percent of time in July in which the weekly average maximum daily stream temperatures are expected to exceed YCT's mortality threshold.

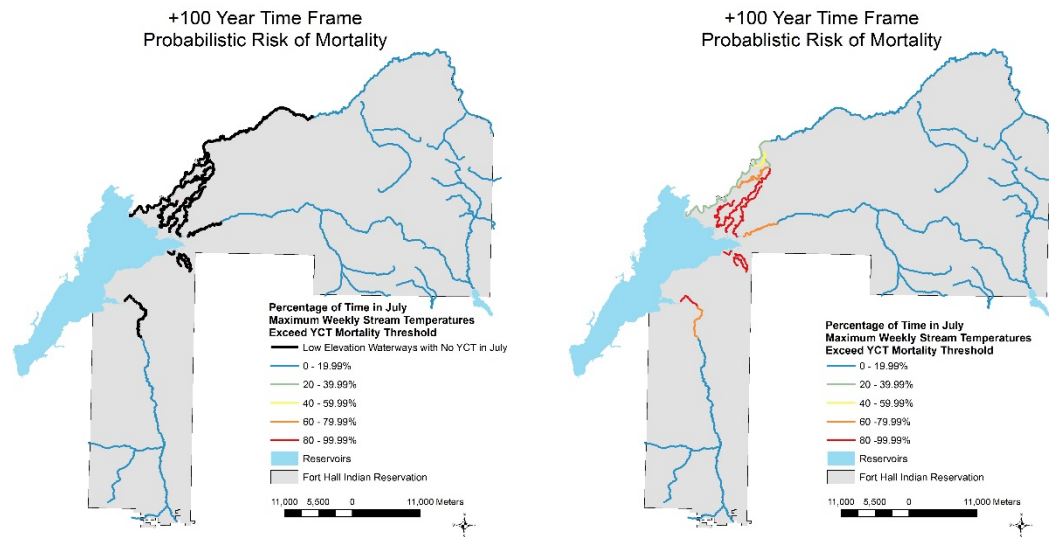


Figure 17: +100 year time frames probabilistic risk of mortality. Black line segments represent waterways with no YCT in July. Maps display the percent of time in July in which the weekly average maximum daily stream temperatures are expected to exceed YCT's mortality threshold.

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