Patrick Jackson

**Geographic Patterns of the Invasive Pathogen PKD in Headwater Streams of the Missouri River**

**Introduction**

Aquatic invasive species (AIS) management is an emerging issue that affects natural, economic, and cultural resources. AIS pose a unique and serious threat in southwestern Montana, the home to the headwaters of the Missouri watershed. The network of interconnected streams and waterways in the area is the perfect launching point for spread of invasive species. The invasive parasite *Tetracapsuloides bryosalmonae*, which causes proliferative kidney disease (PKD) in salmonid species, has recently become a major risk to wild fish populations in this region, costing the state of Montana millions in 2016. The primary predator of PKD infection and virulence is high water temperature, and its thermal habitat is increasing each year with climate change. Additionally, increasingly low river flows and high angling pressure has put heightened stress on fish in this area. The sheer amount of freshwater habitat in the area has made management of PKD extremely difficult. This project seeks to model hotspots of PKD activity in order to better help managers focus on specific areas.

**Methods**

Analysis was conducted on the major streams that make up the headwaters of the Missouri River in southwest Montana. As temperature is the primary predator of PKD, it was looked at first and weighed most heavily. Remotely sensed temperature data from the Montana Climate Office was used to find mean historical August air temperatures. Using these values, water temperature was calculated along the stream’s lengths using the equation: \( T_w = 5 + 0.75 \ T_a \) where \( T_w \) is water temperature and \( T_a \) is air temperature. However, it was determined that this model was inaccurate as it was not developed specifically for the region. So, during August 2019 field measurements were taken every 75 meters of the 84 miles of the Jefferson River. Water temperature at a depth of 2 feet and ambient air temperature were recorded (figure 1). The field values were then used generate a new thermal model in R statistical software (figure 2). Using this model, water temperature values were predicted for the rest of the headwater streams in the region.

Next the two other variables, angling pressure and river flows were looked at. Angling pressure was evaluated using the Montana Fish, Parks, & Wildlife’s angling data to find anglers per year per mile on each river. River flows were looked at in terms of finding the streams with the lowest summer discharge comparative to their annual discharge using data for United States Geological Survey stream gauge stations.

**Results and Discussion**
Using the water temperature model created on the Jefferson River, it was found that highest water temperatures were near Three Forks, Montana which is where the Jefferson, Madison, and Gallatin meet to form the Missouri River. The waters here all had estimated temperatures above 60°F. The coolest areas were the headwaters of each of the river. Exceptions to this were the Beaverhead, Jefferson and East Gallatin Rivers which saw moderate to high temperatures throughout their entire length. The Red Rock River was the coolest overall, and the Jefferson River was the warmest overall. PKD becomes active in large numbers at around 58°F and fish mortalities become higher with each increasing degree. By this criterion, all rivers besides the Red Rock have at least one section that has high propensity for PKD caused fish mortalities during August.

The streams with the highest percent decrease in August flows from the annual mean were freestone rivers, while tailwaters had more even flows throughout the year. The big hole had the largest decrease in flows, most likely due to large amount of snowmelt runoff it receives in the spring months. The East Gallatin and Jefferson Rivers also experienced very low summer flows most likely due to the large amount of water diverted for irrigation. It is also worth noting that the lower Madison experienced significantly low flows during August compared to other dam-controlled rivers. Angling pressure was highest on streams with a combination of high notability and proximity to an urban center. Rivers such as the Madison and Gallatin received angling pressure ten times greater than most other streams in the region.

To analyze the areas of highest PKD risk, the temperature, angling, and discharge models were combined in a weighted overlay, heavily favoring temperature (figure 3). This model highlighted hotspot areas where infection rates as well as stress leading to fish mortality is high. Only the Red Rock River was free form having at least one area of high PKD mortality risk. The entire Jefferson River and Lower Madison were categorized as high risk. The Three Forks area where the Jefferson, Madison, and Gallatin River meet to form the Missouri River is by far the area of most concern with temperatures not only allowing for PKD activity, but high amounts of angling pressure and low summer flows.

Further continuation of this project should focus on the bettering the air temperature estimations and increasing their resolution. Additional focus needs to be put on mapping and categorizing physical features such riparian vegetation, spring creek inputs, and riffle-run pool dynamics. These features have a large effect on the microenvironments found throughout these diverse rivers and would help more accurately pinpoint areas of concern.

Risk for PKD outbreaks will only increase as climate change continues. The Jefferson and Lower Madison Rivers’ relatively high-water temperatures, large drop in stream flows during the summer, and high angling pressure make it the center of concern in regard to PKD fish mortality. Management of the rivers should consider limiting water withdrawal for irrigation in the area as well as continuing to close specific sections of the river to angling when there are warm water temperatures. Management of the Lower Madison should explore trying to increase summer outflows from the Ennis dam. Currently there is no real cost-effective solution to addressing fish deaths caused by PKD. However, modeling this AIS and focusing management on the necessities and areas of highest risk is a good place to start.
Appendix

Figure 1: Water temperatures normalized by average air temperatures over the study period

Figure 3: Danger Zones for PKD Infection and Fsh Mortality