Assessing the Catalytic Effects of Climate Change: *The Transitive Influence of Mountain Pine Beetle Epidemics on High Elevation Stream Production in Western Montana*

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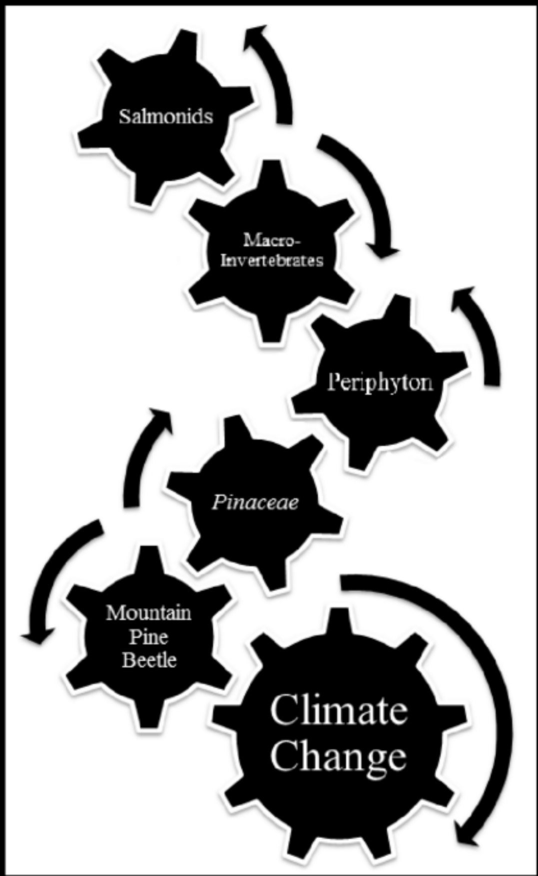
2013 CLIMATE CHANGE RESEARCH PROPOSAL



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Project Description

The goal of this study is to quantify the effects of mountain pine beetle epidemics, induced by climate change, on watershed production. Historical and experimental data will be used to elucidate this relationship. Historical data will be acquired by collaborating with The University of Montana's ecology and fisheries biology departments, and with Montana Fish, Wildlife and Parks. Experimental data will be collected for bioenergetics modeling, within a controlled environment, by using periphyton growth and the subsequent growth of four species of aquatic macroinvertebrates to model population level effects of mountain pine beetle epidemics. Once this relationship has been quantified, additional trophic responses will be integrated into an adaptive model that can be extrapolated to other systems to predict ecological response and guide management action. Guided by Dr. Marczak, this project will benefit from and build on studies currently being performed in the Marczak lab.

Problem Being Addressed

In western Montana, both average and extreme temperatures are increasing at two to three times the global average[27]. This increase in temperature catalyzes a system-wide trophic cascade by enabling the mountain pine beetle (MPB), *Dendroctonus ponderosae*, to extend its range and encroach on previously unscathed high elevation watersheds, resulting in epidemic conditions[1, 7, 22, 30]. Normally, nitrogen is a limiting factor in freshwater systems[34]. When MPB afflicts populations of the family *Pinaceae*, however, nitrogenous input is significantly increased in aquatic systems and can persist above reference conditions for as long as 30 years [18]. This increase of nitrogen in headwater streams transitively affects surrounding watersheds[13, 32, 33] by invigorating periphyton growth on detritus[2, 36, 11, 19]. As a result, macroinvertebrate communities, that contribute at least 10% of total macroinvertebrate abundance found in higher order streams[15], increase production[8, 11, 20]. Macroinvertebrate abundance has been demonstrated to regulate the production of higher trophic organisms that rely on them as a primary food source[29], such as westslope cutthroat trout (WCT), *Oncorhynchus clarkii lewisi*, and bull trout (BT), *Salvelinus confluentus* [25]. Therefore, increasing annual temperatures that expand the range of MPB has the potential to transitively increase WCT and BT production. The goal of this study is to predict higher level trophic production by quantifying the relationship between macroinvertebrate growth and MPB induced allochthonous input. This study will build on previous research[16, 23] by synthesizing existing data and using an experimental approach to integrate relative macroinvertebrate growth rates into an adaptable model for multiple trophic level analysis.

What I Hope to Accomplish

- Quantify periphyton and macroinvertebrate growth rates as a function of pre-MPB conditions and post-MPB conditions.
- Create a non-linear algebraic model that plots growth as a function of varying degrees of conditions induced by MPB.
- Synthesize experimental data with bioenergetic and competition models for higher trophic level production using WCT and BT as model systems.
- Synthesize existing research and experimental data to create an adaptable model to predict stream-specific response to MPB invasion.

Methods *please refer to detailed methods attached with timeline for additional information*

Experimental and historical data will be integrated to create a model that elucidates the effects of the mountain pine beetle on watershed processes. The experimental portion of this project requires stratified random sampling (SRS) of pine needles that are dropped from the tree at different degrees of MPB invasion, and SRS mediated surber sampling of four species of macroinvertebrates that rely on allochthonous input: the nearly ubiquitous stonefly *Yoraperla brevis* and three giant stonefly species from the genus *Pteronarcys*[31]. Once collected, all invertebrates will be identified through a dichotomous key[24] and documented for species diversity and abundance. Two classes of selection (90% of organisms) and one control (10% of organisms) will be used to designate macroinvertebrate groups. Macroinvertebrates will be held in artificial substrate trays modeled after previous studies[10, 16]. 10% of needles per group will be analyzed for nitrogen content and the remaining 90% will be cultured with periphyton collected from a randomly designated stream. Additionally, 10% of the cultured needles will be assayed for decomposition. Macroinvertebrates will be fed until satiation. Needles will be removed and replaced every 72 hours. Macroinvertebrate growth rate will be determined by time and distance between instars and be recorded by photograph. Upon conclusion of the experimental stage of this project, macroinvertebrates will be euthanized in ethanol and statistical tests will be performed, analysis of variance (ANOVA), analysis of covariance (ANCOVA), Turkey's mean comparison test, Bartlett's test for equality, to analyze the different types of data that was collected. Historic data, obtained from MFWP and from regional studies at ecologically similar watersheds, will be used to augment system-wide predictions. Unsampled macroinvertebrate growth estimates will be modeled based on relative scope for growth curves and bioenergetic models under similar conditions. WCT and BT bioenergetic models will be used as model systems for higher trophic level production increases. Predictive models that extrapolate data to additional trophic levels will use the framework of previous studies[14, 21. 28].

Relation to Climate Change and Natural Resources

This study will contribute to the existing body of knowledge on climate change by quantifying transitive effects on watershed production in an adaptable model. In addition to being able to predict changes in productivity as a function of MPB affected watersheds, ecologists and biologists will be able to adapt models from this study to make better informed decisions when assessing restoration goals, making management decisions, and monitoring long term trends in productivity due to climate change. With temperatures in western Montana increasing at two to three times the global rate, this study is regionally significant because it will resolve a key aspect of the system-wide shifts caused by climate change. Although this study focuses on high elevation watersheds in western Montana, this type research also has far reaching effects. Future studies will be able to extrapolate concepts used in this project by adapting the predictions of this research to best fit their model systems. It is imperative that the transitive effects of climate change are modeled to predict long term effects on watershed processes. Although this type of modeling requires an immense amount of information to be accurate, this study seeks to synthesize existing information and to quantify large scale changes in productivity as a function of climate change.

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