AMOD-5610H/5620H

Project Proposal

Woodlands and Waterways EcoWatch (WWEW)

Investigating Benthic Macroinvertebrate Communities in Haliburton County Lakes

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Date: October 16, 2024

Introduction

The ecological health of freshwater lakes is increasingly recognized as a critical component of environmental sustainability, particularly in regions like Haliburton County, where natural resources play a vital role in local communities and biodiversity. Freshwater ecosystems provide essential services, including water filtration, habitat for diverse species, and recreational opportunities. However, these ecosystems face numerous threats from human activities, climate change, and invasive species, leading to shifts in water quality and habitat conditions that can adversely affect aquatic life.

Benthic macroinvertebrates, which include organisms such as insects, crustaceans, and mollusks, inhabit the sediment at the bottom of lakes and rivers. These organisms are integral to the aquatic food web and serve as key indicators of ecosystem health due to their sensitivity to environmental changes. Their presence, absence, or abundance can provide insights into the quality of water and the overall ecological integrity of the ecosystem. For instance, certain species are intolerant to pollution, making them valuable for assessing water quality and identifying potential ecological stressors.

This project aims to investigate the relationships between benthic macroinvertebrate community structure and various environmental drivers in multiple lakes across Haliburton County over a five-year period. The primary objectives include analyzing changes in benthic community composition over time, identifying the key environmental factors influencing these communities, and assessing the influence of trophic status across different riparian zones.

To achieve these objectives, a comprehensive analysis will be conducted using existing datasets that encompass water chemistry, riparian characteristics, and sediment types. The approach will integrate statistical techniques such as Principal Component Analysis (PCA) and more to discern patterns in community structure and their correlations with environmental variables.

The motivation for this study stems from the pressing need for data-driven decision-making in the management and conservation of Haliburton County's aquatic resources. By understanding the dynamics of benthic communities in relation to their environment, stakeholders—including local governments, conservation organizations, and the public—can make informed choices to enhance ecosystem health and resilience. The findings from this study are expected to contribute significantly to the existing body of knowledge and guide future conservation strategies, ensuring the sustainability of Haliburton County's lakes for generations to come.

Literature Review

It is commonly known that benthic macroinvertebrates are useful bioindicators for determining the ecological health and water quality of aquatic habitats. Their usefulness in long-term monitoring programs stems from their sensitivity to different contaminants and changes in the environment. The function of benthic macroinvertebrates in assessing the health of aquatic ecosystems, their reaction to environmental stressors, and their connection to trophic status have all been clarified by a number of studies. In a research published in 2006, Bonada et al.(2006) emphasized the significance of benthic macroinvertebrates in biomonitoring and emphasized how sensitive they are to pollution gradients, including nutrient enrichment and organic contamination. Changes in community composition are discussed as indicators of changes in water quality, especially when species that are vulnerable to pollution, like as Ephemeroptera, Plecoptera, and Trichoptera (EPT taxa), are present. This is essential to comprehending the long-term responses of these creatures to environmental perturbations, which is consistent with the project's analysis of long-term community changes.

The impacts of nutrient enrichment on freshwater ecosystems were investigated by Larsen et al. (2011), with a particular emphasis on the responses of various trophic levels including benthic macroinvertebrates to eutrophication. Their research sheds light on the ways that nutrient imbalances such as an overabundance of phosphorus and nitrogen affect the composition of macroinvertebrate communities. This is especially important to consider when evaluating how trophic status affects your research. Friberg et al. (2011) conducted a pertinent study that investigates the effects of environmental variables on benthic macroinvertebrate populations. These drivers include temperature, pH, and changes in land use. The scientists discovered that by raising sedimentation and nutrient levels and thus changing benthic communities, anthropogenic activities like deforestation and agricultural runoff had a substantial impact on the general health of the waterbody. These results offer a framework for determining the main environmental factors influencing the populations of benthic macroinvertebrates in the lakes of Haliburton County.

A comprehensive investigation on the suitability of benthic macroinvertebrates as water quality indicators in various freshwater habitats across Europe was carried out by Hering et al. (2006). Their results highlight the validity of evaluating a variety of pollutants, such as pesticides, heavy metals, and organic pollutants, utilizing macroinvertebrate populations. Contextualizing the heterogeneity in your dataset from Haliburton County lakes requires highlighting regional differences in macroinvertebrate population responses to environmental stresses, which is another important aspect of the study.

Dataset

The dataset for this project consists of benthic macroinvertebrate sampling data collected from multiple lakes in Haliburton County over a five-year period. The dataset is structured to capture both environmental conditions and biological data, allowing for comprehensive analysis of the relationships between environmental factors and benthic macroinvertebrate community structure.

- **Attributes:**

Environmental Variables:

Water Chemistry:

Water Temperature (°C): Measured at each sampling event, as temperature affects metabolic rates and species distributions.

Dissolved Oxygen (DO) (mg/L): Indicates oxygen levels available for aquatic life, with higher levels generally supporting more diverse benthic communities.

Conductivity (µS/cm): Reflects the concentration of ions in the water, which can indicate nutrient levels and pollution.

pH: Measures water acidity/alkalinity, which influences the availability of nutrients and affects organism health.

Riparian and Habitat Characteristics:

Riparian Vegetation: Documented in three zones (1.5-10m, 10-30m, 30-100m from shore), covering types such as forested areas, which impact runoff and sedimentation.

Sediment Composition: Describes the dominant and secondary mineral substrates at each sampling location (e.g., gravel, sand, cobble). These physical characteristics determine habitat suitability for different benthic species.

Macrophyte Coverage: The presence of emergent, floating, and submergent plants is noted, as macrophytes provide habitat structure and affect nutrient dynamics.

Algae Presence: The dataset records floating, filamentous, and attached algae types, which can influence food availability and habitat conditions for benthic communities.

Benthic Macroinvertebrate Data:

Species Counts: The dataset includes counts of key taxa, such as Ephemeroptera (mayflies), Trichoptera (caddisflies), Amphipoda (shrimps), and Chironomidae (non-biting midges). These organisms are widely used as biological indicators, with some being more sensitive to pollution and environmental changes than others.

Diversity and Abundance Indices: The dataset also provides metrics like Simpson's Diversity Index and the Hilsenhoff Biotic Index, which help quantify species richness and community composition in relation to environmental quality.

Sampling Event Information:

Date and Time of Sampling: Provides temporal context for analyzing seasonal and annual changes in benthic communities.

Geospatial Information (Latitude/Longitude): The precise location of each sampling site is included, allowing for spatial analysis across lakes.

Sampling Effort: Information about the length of sampling areas and the time spent sampling helps standardize comparisons between sites.

Size and Format: The dataset consists of multiple Excel spreadsheets, with separate sheets for each lake and rows representing individual sampling events. Environmental and biological data are stored in numerical or categorical formats, ready for statistical analysis. Each lake has been sampled multiple times, resulting in thousands of observations across the five-year period, with each sampling event contributing about 50-100 individual data points.

Assumptions:

Temporal Stability: We assume that water chemistry and riparian characteristics do not change drastically within short time periods. For instance, measurements of pH, DO, and conductivity are considered representative of the lake's general conditions during the sampling period.

Data Consistency: The sampling methods have remained consistent across all years, meaning that differences observed in the data reflect genuine changes in the environment or benthic communities, not artifacts of differing methodologies.

Spatial Homogeneity: Within each lake, the sampling sites are assumed to be representative of the overall lake conditions, though some heterogeneity may exist due to varying local conditions such as inflows and human activities.

This rich dataset will allow us to perform robust statistical analyses to explore the drivers of benthic community structure, identify trends over time, and assess the health of the lakes in the context of their surrounding environments.

Methodology

We will employ a combination of multivariate statistical techniques to investigate the relationships between environmental variables and benthic macroinvertebrate community composition. The primary methods are Principal Component Analysis (PCA) and Permutational Multivariate Analysis of Variance (PERMANOVA).

Principal Component Analysis (PCA):

PCA is a dimension-reduction technique that helps identify patterns in high-dimensional datasets by transforming the data into a set of principal components. Each component represents a combination of environmental variables (e.g., pH, DO, conductivity) that contribute the most to variation in benthic diversity. PCA will allow us to reduce the complexity of the dataset and highlight which environmental factors have the greatest influence on community composition. The output will provide a visual representation (e.g., biplots) that shows the relationships between environmental drivers and benthic taxa.

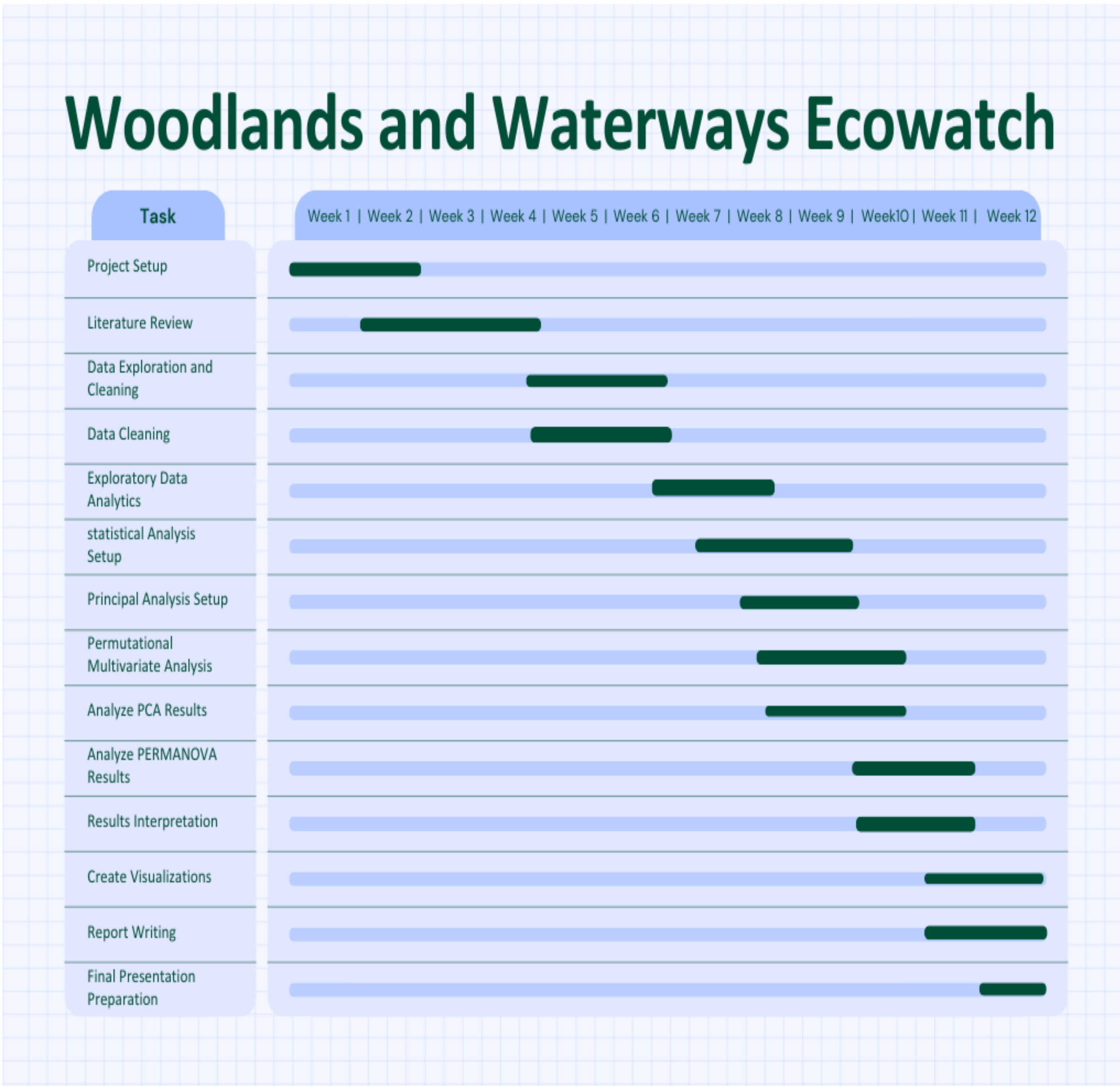
Permutational Multivariate Analysis of Variance (PERMANOVA):

PERMANOVA will be used to test for significant differences in benthic community structure across various environmental gradients, such as water chemistry, riparian zones, and sediment types. Unlike traditional ANOVA, PERMANOVA is well-suited for ecological data, which often violates assumptions of normality. It uses permutation tests to evaluate the significance of the observed differences, making it a robust choice for assessing community-environment interactions. This method will help identify how benthic diversity varies across different lakes and environmental conditions, particularly in headwater systems.

Other Considerations:

In addition to PCA and PERMANOVA, we may calculate diversity indices (e.g., Simpson's Diversity, Hilsenhoff Biotic Index) to quantify ecological health and explore specific taxa responses to environmental changes.

Project Plan



Citation

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