Making Optimal Decisions for an Uncertain Future: Quantifying the Effects of Anthropogenic Disturbance on Biodiversity and Ecosystem Services

Key Words: *Disturbance Effects, Biodiversity, Ecosystem Services, Ecosystem Management*

Introduction: Anthropogenic disturbances negatively impact species, genetic and functional diversities of ecosystems, reducing the essential services they provide. While we know that the presence of diverse functional traits in an ecosystem is directly linked to the successful provisioning of essential services[1], it is often easier to quantify an ecosystem's genetic diversity than to determine its functional diversity. Unfortunately, we lack a fundamental understanding of the interrelationships between these forms of diversity and whether or not one can be used as a proxy for another. This gap in our knowledge impedes our ability to make management decisions that maximize future ecosystem services. My proposed research will:

Research Objectives:

1. Determine if and how genetic diversity and functional diversity are related.
2. Determine if and how natural and anthropogenic disturbances alter the relationship between genetic diversity and functional diversity.
3. Create a predictive management tool that allows us to maximize genetic and functional diversity, and thus the provisioning of ecosystem services, in the uncertain future.

To accomplish these objectives, I will develop a database of the species present before and after anthropogenic disturbances. The database will contain data from a global range of ecosystems, as well as a subset of data that will be provided by Sierra Pacific Industries (SPI), the largest private landowner in California. I will analyze these data to determine how genetic and functional diversities change after disturbance and then create an easy-to-use online management tool that predicts how future anthropogenic disturbances will alter biodiversity and ecosystem services.

Background: Phylogenetic Diversity (PD) is the length of evolutionary pathways connecting taxa, and it is a well-known index used to measure genetic diversity[2]. When managing an area to conserve overall biodiversity, maximizing PD is likely the best way to hedge our bets and increase the probability of having the right extant species at our disposal in a future of unknown environmental, economic, and medical needs[3]. Functional diversity (FD), the total branch length of a tree of functional traits, measures the diversity of functional traits in an area[4]. Maximizing the FD of an area is important because essential ecosystem services are directly tied to the value, range, and abundance of an ecosystem's functional traits[1].

It is quickly becoming more practical and economical to determine the PD rather than the FD of an ecosystem because DNA barcoding can reliably complete large taxonomic surveys, while quantifying the functional traits present in an area is still a large undertaking. It is possible that PD can serve as a proxy for FD, which would allow us to assess an ecosystem's function without quantifying functional traits. However, no large-scale study has ever demonstrated the relationship between genetic and functional diversities. Additionally, we currently have no way to accurately predict the effects of anthropogenic disturbances on PD and FD.

SPI owns approximately 1.7 million acres of land and must routinely make management decisions without knowing the exact consequences of their management practices. SPI is interested in learning if their management causes changes to the biodiversity and ecosystem services of their land. Therefore, in addition to studying disturbances in a range of global ecosystems, I will collaborate with SPI to determine the effects of harvesting-related disturbances.

Methods: I am currently collecting data from published articles that document changes to the species diversities of a range of organisms after anthropogenic disturbances (e.g. fire, timber extraction) in ecosystems subject to diverse natural disturbance regimes (e.g. fire, flooding). SPI has already compiled a dataset that details the plant species observed before and after clearcutting, replanting, and applying herbicides in 200 forest patches. With this data, I will:

1. Build separate phylogenetic and functional trees of species found before and after human disturbance, using known phylogenies, programs such as Phylomatic and TreeBASE, and lists of functional traits, such as USDA PLANTS and Jepson Herbarium's Flora Project.
2. Analyze relationships between disturbance, PD, and FD. Using a likelihood and Bayesian approach, I will compare changes to PD and FD after disturbance and changes in the K score of trees, which is the difference in the relative branch lengths and topologies of phylogenetic trees[5]. If PD and FD change in correlated ways after disturbances, then PD can serve as a proxy for FD. I will also determine if the changes in PD, FD, and K score can be explained by specific disturbance regimes.
3. Organize data and results in an SQL database. Create an accessible online tool that will be available to researchers, landowners, government, and NGOs. It will formulate ecosystem management plans and allow users to predict how their actions will change their land's biodiversity and ecosystem services. I will also develop a California version for use by SPI.

Expected Results:

1. Ecosystems with a high PD will have a correlated high FD.
2. If an ecosystem faces an anthropogenic disturbance that mimics its natural disturbance regime, PD and FD will change in correlated ways, and PD can serve as a proxy for FD.

Broader Impacts: Large-scale biodiversity loss directly threatens ecosystem stability and reliability by impairing ecosystem services, such as primary production, carbon storage, and pollination[1]. Gaining a better understanding of the effects of our ecosystem management decisions will allow us to avoid the irreversible loss of biodiversity and ecosystem functions or to at least limit the scale, frequency, and intensity of anthropogenic disturbances in the future. My research findings will elucidate the relationships between genetic and functional diversities. I will provide the information and tools we need to make economically efficient and socially optimal resource management decisions, ensuring that we conserve the organisms that will provide essential ecosystem services in an uncertain future.

I have already started data collection for this project, and I am currently mentoring three undergraduates, including two women who also belong to ethnic minorities, who are aiding in the development of my dissertation project. After developing the management tool, I will hold workshops for landowners throughout California. I will teach them to use the tool, and I will speak on the benefits of managing land to maximize biodiversity and ecosystem function. My research will inform the long-term management decisions of landowners in California.

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