GARDEN ISLES OR GHOST FORESTS: EFFECTS OF DISEASE-DRIVEN DEATH OF THE DOMINANT TREE ON HAWAIIAN FORESTS.

Imagine the leafy tropical gardens of Hawaii’s native forests, vibrant with native birds and insects that thrive under the native ohia tree’s canopy, converted to silent grey tree trunks and bare branches. This is the experience in parts of northern California where the tree disease Sudden Oak Death has decimated forests and changed the composition of trees, birds, and animals in the forest (*1*, *2*). This is the scenario now playing out across the island of Hawai’i. Native forests replete with endemic plants, birds, and insects that evolved under the canopy of the dominant tree, ohia, are threatened by Rapid Ohia Death (ROD), a new disease that can kill ohia and may cause extensive tree mortality across the islands (*3*). Our research asks ***1) How will Rapid Ohia Death spread among ohia individuals and populations?*** *and* ***2) How will the subsequent death of ohia affect other forest species?***

*Predicting disease spread*.—On Hawaiian islands, ohia (*Metrosideros polymorpha*) occurs in high numbers throughout wet and dry forests from sea level to tree line (*4*, *5*). Rapid Ohia Death (ROD) is caused by the fungal pathogen *Ceratocystis fimbriata*, a pathogen of potatoes that has begun to cause mortality in ohia by disrupting trees’ circulatory systems (*3*). The disease can kill over half (possibly as high as 90%) of trees in forest patches as large as 100 acres; it has affected 6,000 – 30,000 acres of forest across the island of Hawai’i (*6*, *7*). The disease continues to spread, but biologists remain uncertain where it will spread and how many trees it will infect and kill.

Our work to predict disease spread will identify the characteristics of ohia trees, forests, and the environment that encourage the disease to spread. We can identify risk factors that increase tree susceptibility to the disease and those that increase transmission of ROD. This information may help managers and policy makers design effective and minimally inhibiting disinfection protocols or quarantines for forest users. By sharing our predictions with the State of Hawaii, US Department of Agriculture, and US National Park Service, we may help stem the spread of ROD and mitigate its effects on forests.

We will use mathematical models of infectious disease dynamics, parameterized with field data, to predict how ROD will spread across the island of Hawai’i. We will combine our experience in disease and forest ecology with data shared by future collaborators to identify characteristics of ohia (like size, density, proximity to other ohia) and the environment (rainfall, soil type, forest patch size) that determine whether a tree becomes infected, how quickly it dies, and how many other trees it can infect. To parameterize and test models of disease spread, we will use existing and future data from citizen reports, aerial surveys (e.g., the Carnegie Airborne Observatory: https://cao.carnegiescience.edu/), and a network of long-term forest research plots (http://www.fia.fs.fed.us/).

*Measuring effects on other species.—*Ohia is the tree that first takes hold on bare lava rock (*8*), and as the forest develops, it feeds and shelters native plants, birds and insects that have coevolved with it (*9*, *10*). As ROD kills trees, the plants and animals that depend on ohia will lose a resource, while other plants respond by taking advantage of shade free space and unabsorbed soil water (*4*) and may promote a new set of birds and insects. Because of its ecological importance, the loss of ohia may have disproportionately large consequences for the community.

As the world’s biodiversity declines, consequences include the loss of products and services that benefit humans. For example, ohia provide flowers used in Hawaiian traditions (*11*), and they help soil and vegetation develop on exposed lava (*4*, *8*). We can expect these benefits to decline with ohia. By describing and predicting how ROD affects forest communities, we can help Hawaii’s resource managers protect areas where ohia declines would have especially severe impacts on ecosystem services and on already threatened plants and animals.

This disease outbreak presents a rare opportunity for us to study the ecological effects of declining biodiversity using a valuable approach: in killing only ohia, the disease effectively creates an experiment in which a single species is removed from a community. For ecologists, this is akin to removing a single brick in a wall, and seeing how the other bricks – other forest species – fall or stay put, which allows us to measure whether that one brick – ohia – is a “keystone” upon which the entire community depends (*12*). As we continue to face biodiversity loss, studies like this help us generalize the consquences of species’ declines.

We intend to measure and predict those consequences for Hawaiian forests. Our initial identification of ROD susceptible forest patches will allow us to select sites for this naturally occurring experiment. We will identify a set of forest patches that vary in ohia mortality levels, from pre-exposure to five years post-epidemic, controlling for forest patch age and size, and we will work with local biologists to track the changes in plant, bird, and insect communities using standard sampling techniques. We will survey birds using timed bird counts, insects using a variety of trap types in the understory and the canopy, and plants by identifying size and species of all stems >1 cm diameter at breast height (DBH) and the percent cover of understory vegetation along random transects. We will sample each forest patch three times during the year to assess potential seasonal changes in plant, bird, and insect communities in response to ohia loss. The before and after comparison, and the size of the difference, will help us to assess ohia’s role as a keystone species in Hawaiian forests.

*Conclusion.—* As we measure how ROD spreads and affects Hawaiian forest communities, we can provide information to aid forest protection and conserve plants and animals that depend on ohia. As a new epidemic unfolds, even the most basic information about disease spread and impact is unknown. The Hellman award provides an opportunity to collect pilot data that can seed a larger research program in Hawaiian forest change, conservation, and regeneration. Moreover, we see this disease outbreak as an opportunity to study the importance of species and the consequences of biodiversity loss. This research is urgent and timely, because continued loss of healthy forests eventually reduces our ability to rigorously compare them to diseased forests. Once surrounded by the ghostly grey, leafless trunks of the trees that support Hawaii’s island gardens, it may be too late to ask “Why are ohia important?”

Budget:

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| --- | --- | --- |
|  | Field/lab technician: $23.18.00 / hour x 612hours | 14515.66 |
|  | Graduate research assistant: 50% for 1 academic quarter | 4649.00 |
|  | PI travel: Airfare @ $600.00 + hotel @ $100.00 / night x 14 nights | 2000.00 |
|  | GRA travel: Airfare @ $600.00 + hotel @ $100.00 / night x 14 nights | 2000.00 |
|  | Post-doc travel: Airfare @ $600.00 + hotel @ $100.00 / night x 14 nights | 2000.00 |
|  | Post-doc community modeling (25% of post-doctoral researcher salary) | 12900.00 |
|  | Equipment: |  |
|  | Disinfectant: Bleach @ $100 / 12 gallons  Rubber boots: 2 pairs x 2 people @ $20.00 each  Tree measuring equipment:  Densiometer: 2 @ $100.00 each  Meter tapes: 2 @ $30.00 each  Insect trapping equipment:  Malaise traps: 4 @ $250.00  Sticky traps: 100 @ $0.40 each  Whirl paks: $50.00  Ethanol: 5 gallons @ $40.00 each  Bird tools: binoculars @ $100.00 x 2 | 100.00  80.00  200.00  60.00  1000.00  40.00  50.00  200.00  200.00 |
|  | Total | 39994.66 |

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