GARDEN ISLES OR GHOST FORESTS:

DISEASE-DRIVEN DEATH OF THE DOMINANT TREE   
IN NATIVE HAWAIIAN FORESTS.

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Where green leafy trees stood, imagine just bare grey branches and visible trunks; imagine the birds and insects that used to live in those trees, now gone. This has happened in forest patches throughout Northern California, as the tree disease Sudden Oak Death has killed oak trees, changing which trees thrive in the forest and which birds and animals a hiker is likely to see in the forest ().

Imagine the same scenario, magnified, throughout the Hawaiian islands. Rapid Ohia Death (ROD) is a new disease of Hawaii’s dominant tree species, the ohia (), and it has the potential to cause extensive tree mortality, and dramatic changes in native forest vegetation and to the unique, endemic birds and insects that have co-evolved with Hawaii’s vegetation (). We are starting a research project to answer two questions:

1. ***How will Rapid Ohia Death spread among ohia individuals and populations?***
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 (). Rapid Ohia Death (ROD) is caused by the fungal pathogen *Ceratocystis fimbriata*, previously a pathogen of potatoes, and has begun to cause mortality in ohia by disrupting a tree’s circulatory system (). It has affected over 6,000 acres of forest across Hawai’i island, causing 50-80% ohia mortality in patches from 1 to 100 acres ().

Our goal is to predict how the disease will spread and how extensive its effects on ohia will be. This work is important because we can identify the characteristics of ohia trees, forests, and the environment that help the disease spread. Sharing our predictions with the State of Hawaii, US Department of Agriculture, and US National Park Service, we can help them stem the spread of ROD and mitigate its effects on forests. We can identify risks that increase the transmission of ROD or trees susceptibility to the disease. This information may also contribute to design of disinfection protocols, allowing ohia to maintain its role in Hawaiian culture.

We will use computer simulations to predict how ROD will spread across Hawai’i. Based on our knowledge of disease ecology and forest ecology, complemented by data shared by future collaborators, we identify the characteristics of ohia (age, size, phenology, population density, insect pests) and the environment (rainfall, wind patterns, nearby tree species, human use) that determine whether a tree becomes infected, how quickly it dies, and how many other trees it can infect. We will use existing data from citizen reports, aerial surveys, and a network of long-term forest monitoring plots. Ultimately we will produce academic articles, as well as maps and presentations for the public.

*Measuring effects on other species.—* As the dominant tree in Hawaii’s forests, ohia feeds, houses, and has coevolved with native bird and insect species (). Secondly, ohia is the tree that colonizes new unvegetated lava, and it battles for light and water as forests age and other species take root (). Ohia is ecologically important, and as ROD kills ohia trees, the animals and plants with which it interacts will lose or gain resources. Like most trees, it has the potential to be a foundation or ‘keystone’ species that has a disproportionately large influence on the fate of the plants and animals that live in, on, or around it (). This includes some of Hawaii’s endemic birds like the honeycreepers, which drink nectar from ohia flowers and act as pollinators. We predict that forest patches affected by ROD will have vegetation, birds, and insects that are distinct from those found in healthy, pre-ROD forest communities. Birds and mobile insects will decline in affected patches but take up residence in nearby intact forests (). Less mobile animals, like spiders, may actually decline as their habitat changes beneath them ().

Describing and predicting how ROD affects forest communities is important because it may help identify forest patches where plants and animals will be most affected by ohia death, or patches where already threatened species might be further threatened by loss of resources or changes in habitat. What we learn about how ROD indirectly affects non-ohia species can help Hawaii’s resource and wildlife managers focus their forest protection efforts on areas where ROD would have especially severe consequences for already threatened plants and animals, versus areas where some tree loss may be acceptable because secondary effects might be less severe. Because of the scale of work required, this study of a whole community will benefit from bio-blitz like activities in which citizen-scientists help detail the species diversity of a region.

As the world’s biodiversity declines, scientists strive to understand the benefits of diversity for other species and on humans. As we lose species, we also lose services and products. For example, ohia forests provide flowers used in Hawaiian traditions, water quality, and perhaps even human disease prevention (), and we can expect these to change along with disease-driven forest changes. We also know that species vary in their ‘importance’, but this knowledge generally comes from small experiments or simulations in which an animal was physically or digitally removed from a habitat (). Disease outbreaks offer an opportunity to examine the importance of a species at the scale of hundreds of acres or years; because a disease generally kills only one species in a community, we allow disease to remove a particular species and perform our experiment for us.

To investigate the effect of ROD on forest communities we will assemble an interaction network, much like a social network or a food web, that is centered on ohia. Combining this network with our predictions of how ROD will spread (Question 1), we will identify forest patches likely to be struck by ROD, then use ROD outbreaks as a naturally occurring experiment that changes the forest. We will describe what plants and animals are present in these patches before and after ROD outbreaks. We will also cooperate with island scientists to use ongoing, long-term, forest monitoring plots to examine vegetation, birds, and insects at a larger scale as forests change over time. Using the data we collect about the response of the community to ohia death, we will create a predictive computer simulation that shows how the disease will spread and how it can affect a range of sensitive species across Hawai’i.

*Conclusion.—* We have the opportunity to study big ecological questions about emerging infectious disease, the importance of species, and the consequences of biodiversity loss. As we study how ROD spreads and affects Hawaiian forest communities, we can provide information to aid forest protection and help the other plants and animals that depend on ohia, many of which are already also threatened. This research is urgent and timely, because it becomes more difficult and less important if we wait until the disease has already decimated much of the forest. It may be too late to ask ‘why is this species important’ once we are surrounded by the ghostly grey, leafless trunks of a tree that was the foundation of island gardens.

*Budget Justification.—* In the first year of our study, our research efforts will focus on collecting data to help us construct our disease spread model and our ohia-interaction network model, as well as to start collecting data in healthy forest patches that are currently naïve but are likely to be affected by ROD, so we require some field work equipment and a technician to perform that field work. To minimize spreading disease to uninfected forests, we will purchase pairs of most field gear for use in infected vs. uninfected forests. As importantly as collecting data is developing relationships with local biologists and forest managers already familiar with ohia declines and the natural history of Hawaiian forests; these relationships will be stronger

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|  | Item | Cost |
|  | Field technician wages: $\_\_.00 / hour x \_\_\_hours |  |
|  | PI travel: Airfare @ $600.00 + hotel @ $100.00 / night x 14 nights | 2000.00 |
|  | Equipment: |  |
|  | Disinfectant: Bleach @ $100 / 12 gallons  Disposable gloves:  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 | 100.00  80.00  200.00  60.00  1000.00  40.00  50.00  200.00  100.00 |
|  | Overhead? |  |
|  | Total requested: |  |