Project Title: Determining and Monitoring the Influences of Rapid 'Ōhi'a Death on the Current and Future Status of Hawaii's Native Forests

Agency, Division: Institute of Pacific Island Forestry, Pacific Southwest Research Station, USDA- Forest Service

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Partner Agencies: USDA-Agricultural Research Service, Hawaii Department of Agriculture, DLNR-DOFAW, University of Hawaii.

Project Objectives: Determine the manifestation of *Ceratocystis*-induced Rapid ʻŌhiʻa Death (i.e., ROD) – its distribution, patterns, and impacts - among ʻŌhiʻa forests across Hawaiʻi Island. We established and monitored in a detailed fashion, 183 ROD monitoring plots to determine ʻŌhiʻa annual mortality rates. We have identified the specific species of *Ceratocystis* (i.e., species A, B, or something else) responsible for mortality of individual trees through time, and we characterized physical (e.g., lava substrate and age, climate) and biological factors (e.g., stand age and forest composition) that correlated with distributions and impacts of the disease. Resulting information will be instrumental to informing additional critically needed management efforts.

Background: ʻŌhiʻa lehua (*Metrosideros polymorpha*) accounts for 50% of all trees, native or non-native, and 50% of the total basal area on Hawai'i Island. Further, it comprises 80% to >90% of the trees across all of Hawaiʻi's native forests (i.e., 865,000 ha statewide and 620,000 ha on Hawai'i Island). Collectively, ʻŌhiʻa forests support enumerable native plant and animal species and overwhelmingly constitute the watersheds that provision Hawaiʻi's citizens with abundant, clean drinking water. Rapid ʻŌhiʻa Death (ROD) caused by the primary fungal pathogen *Ceratocystis fimbriata* threatens Hawaiʻi's ʻŌhiʻa forests statewide and has caused extensive stand level mortality across approximately 70,000 acres of ʻŌhiʻa forests on Hawaiʻi Island. This represents more than 10% of that Island's ʻŌhiʻa-dominated forests. Where the disease is present, ʻŌhiʻa annual mortality rates average about 10%. The dearth of ʻŌhiʻa seedling recruitment and characteristic understory dominance of non-native species documented within many of the established plots, coupled with the lethality of *C. fimbriata* to ʻŌhiʻa, suggest that these forests will be dominated by non-native species in the future in the absence of effective management approaches.

As part of the overall Rapid ʻŌhiʻa Death forest impact project, we utilized HISC funding to partially support one FTE biological technician position to work within a larger team of Biological Technicians coordinated by Hughes (USDA-Forest Service) to monitor manifestation of *Ceratocystis fimbriata*-induced Rapid O'hi'a Death (ROD) – its distribution, patterns, and impacts – among a broad array of O'hi'a (*Metrosideros polymorpha*)-dominated stands across Hawaii Island where symptomatic ROD trees were detected by aerial imagery or land manager input.

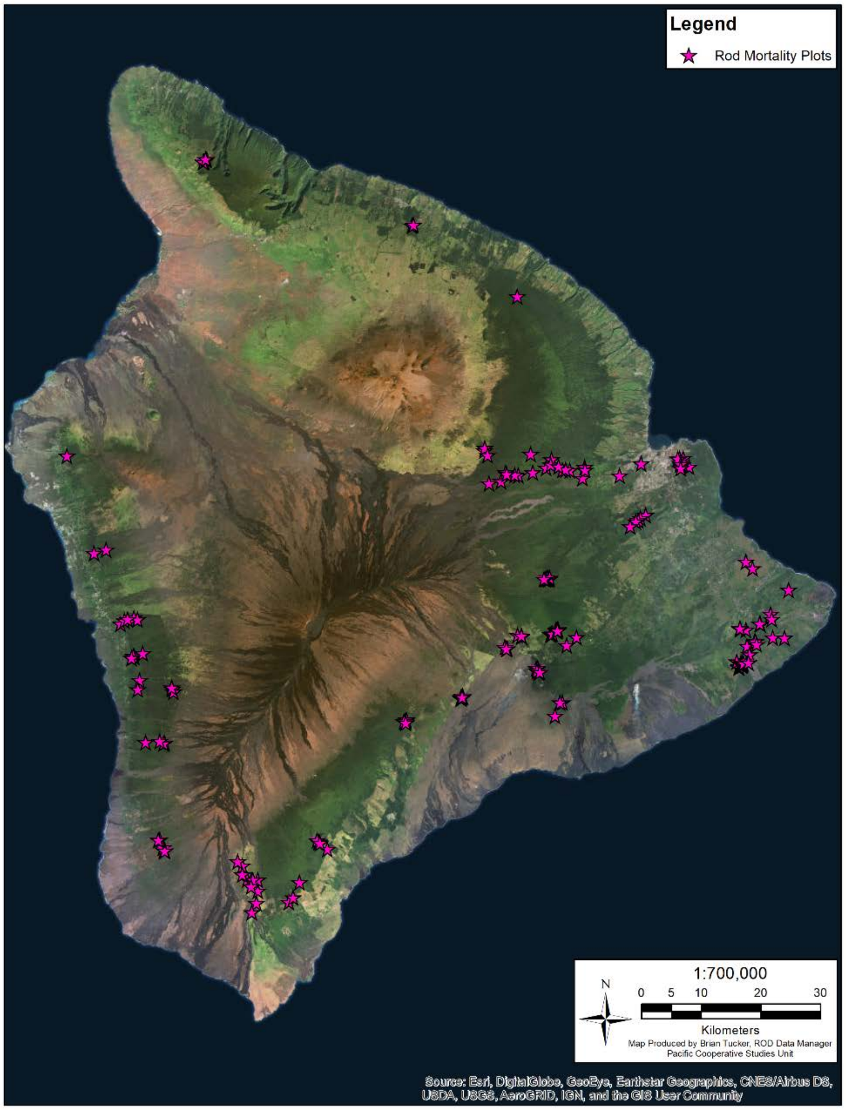

Figure 1. Locations of Rapid ʻŌhiʻa Death Monitoring plots across Hawaii Island.

To date, a total of 183, 0.1 ha monitoring plots have been installed and are being monitored on an annual interval in order to track the manifestation of the disease. Plots are located across areas of Hawaii Island where *Ceratocystis*-infected trees have been detected or are suspected to occur based on extensive sampling of individual suspect trees located across the island (Figure 2). Monitoring plots occur in ʻŌhiʻa -dominated forest stands that range widely with respect to substrate age (i.e., from 64 to 190,000 years before present), mean annual precipitation (i.e., from

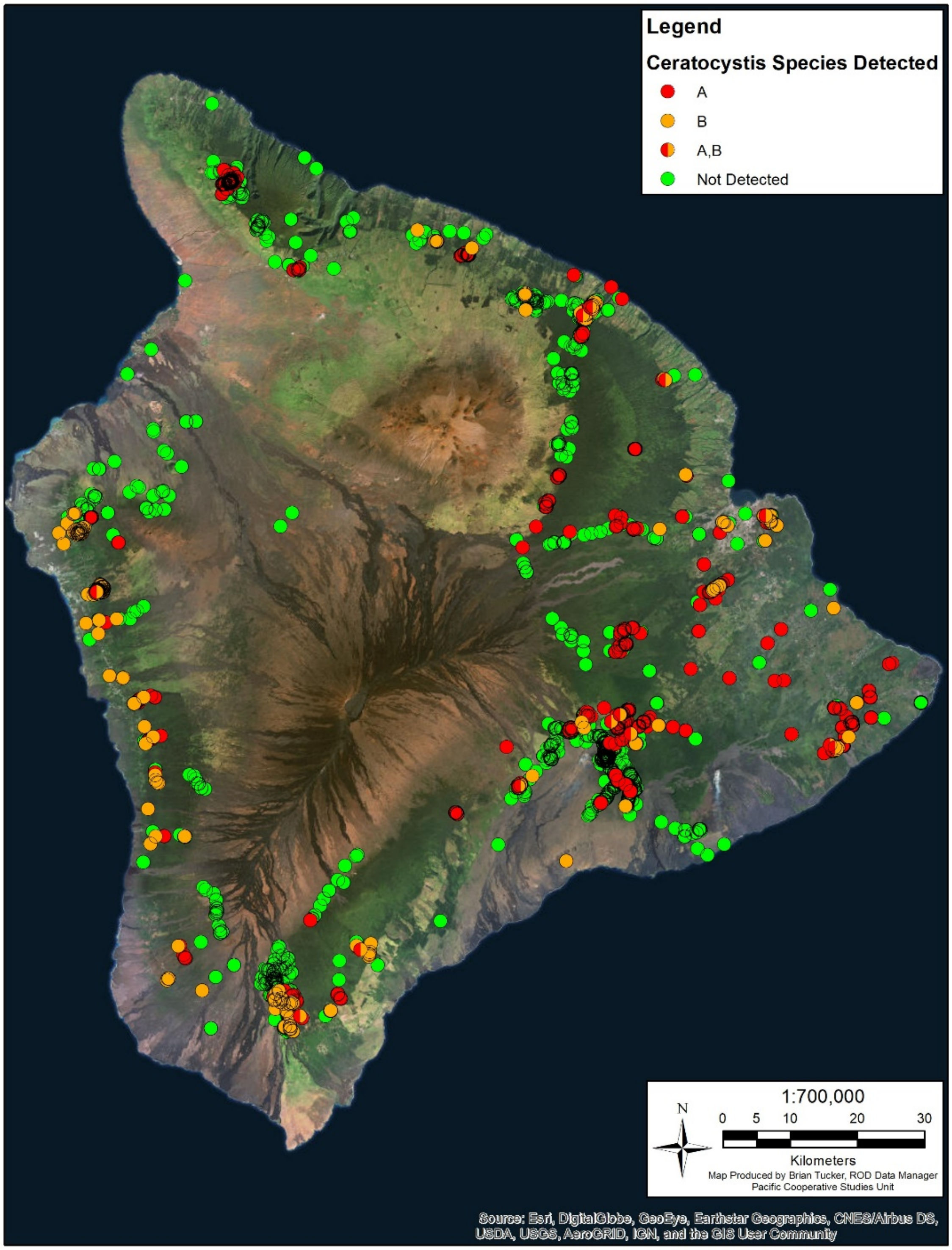

Figure 1. Map of ROD Samples collected on Hawaii Island and tested for presence of Ceratocystis lukuohia *(i.e., Species A) and* C. huliohia *(i.e., Species B)*

798 to 6273 mm), and mean annual temperature (i.e., from 13 to 23 °C). Results to date indicate that in forest stands where *C. lukuohia*-infected trees occurred, annual mortality rates of ʻŌhiʻa averaged approximately 10% (Figure 3). In contrast, annual ʻŌhiʻa mortality rates were substantially lower in forest stands where only C. huliohia-infected trees were present (i.e., < 2%) or where neither Ceratocystis species was detected but where trees showed ROD-like symptoms (i.e., annual mortality rates of 1%). Particular plots exhibited rates as high as 44%, while others exhibited 0% mortality in forest stands where *Ceratocystis*-infected trees were confirmed present (Figure 4).

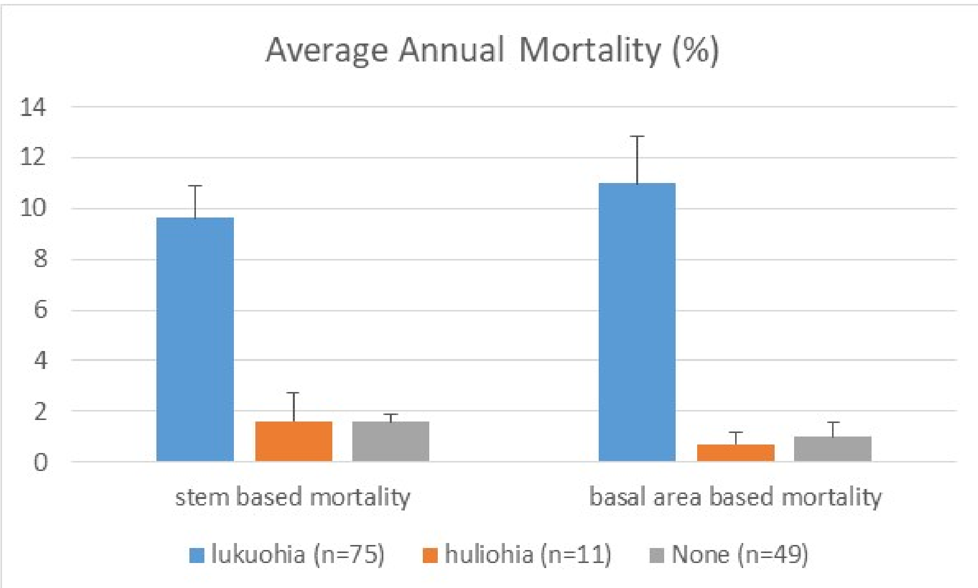

Figure 3. Mean and standard error values of annual ʻŌhiʻa mortality measured in forest mortality plots where C. lukuohia-*infected trees were located (blue bars, 75 forest plots),* C. huliohia-*infected trees were located (orange bars, 11 forest plots) and where neither* Ceratocystis *species were detected (grey bars, 49 plots).*

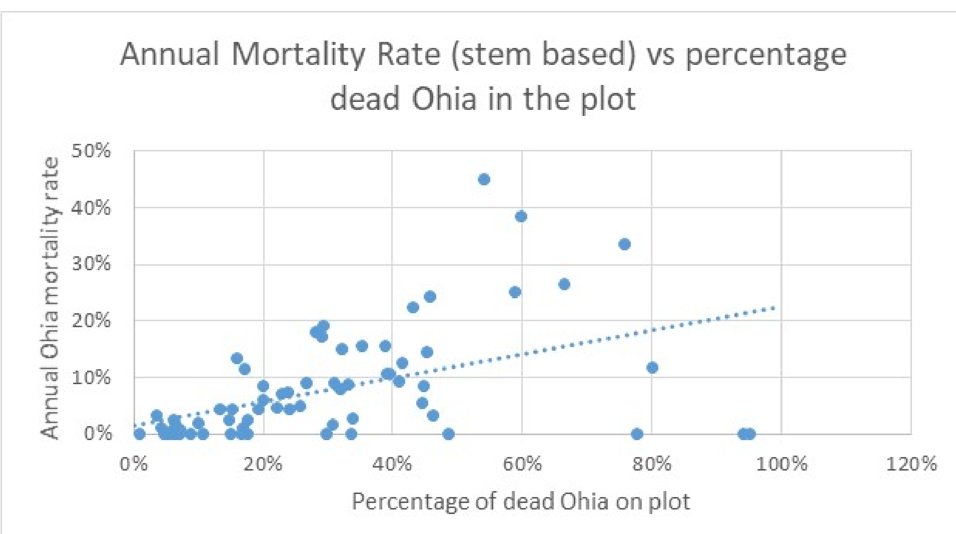

Figure 4. Relationship between annual ʻŌhiʻa mortality rates and the proportion of dead ʻŌhiʻa trees on each plot where C. lukuohia-*infected trees were located.*

Results showed a strong and positive relationship between overall levels of mortality manifested on a given plot where *C. lukuohia*-infected trees occurred and the annual rate of ʻŌhiʻa mortality expressed on that plot (Figure 4). That is, higher rates of mortality are found in areas where high levels of mortality have occured, suggesting that intrinsic site characteristics might in part be responsible for disease impacts (i.e., mortality).

Results clearly indicated that younger, smaller stature ʻŌhiʻa stands exhibit lower annual rates of mortality compared to older, larger stature ʻŌhiʻa stands, and lower annual rates of mortality were found in ʻŌhiʻa stands occurring on young stands growing on 64 year old lava flows compared to rates on relatively older flows (i.e., 300 to 1,500 y. o.) in Puna (Figures 5 and 6). This may be due to any number of factors that need further investigation.

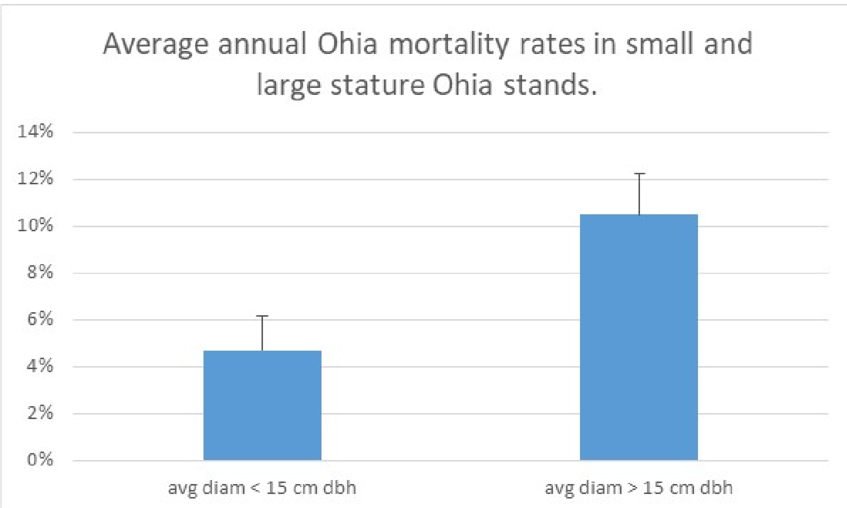

Figure 5. Difference in average annual ʻŌhiʻa mortality rates between small stature ʻŌhiʻa forests (i.e., average trunk diameter < 15 cm dbh) and large stature ʻŌhiʻa forests (i.e., average trunk diameter ≥ 15 cm dbh) where C. lukuohia*-infected trees were located.*

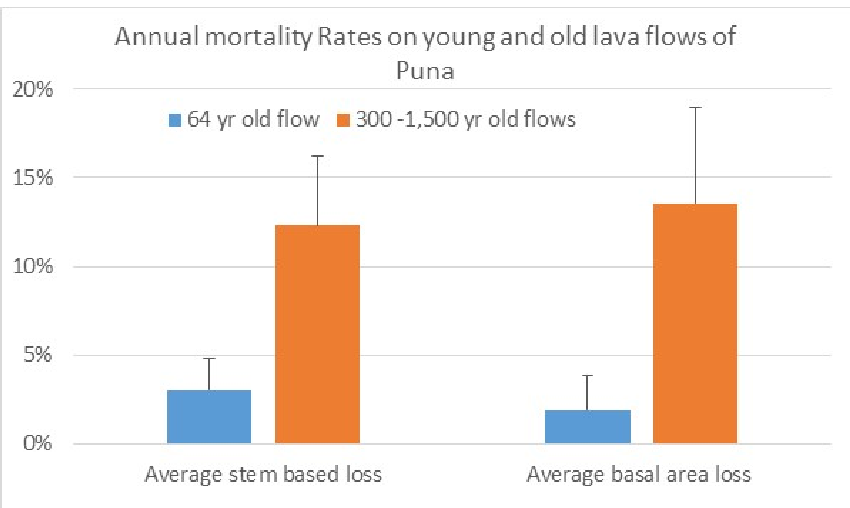

Figure 6. Difference in average annual ʻŌhiʻa mortality rates between ʻŌhiʻa forests occurring on relatively young lava flows (blue bars) and ʻŌhiʻa forests occurring on older lava flows in the Puna District of Hawaii Island where C. lukuohia*-infected trees were located.*

Mean annual mortality rates of plots based on stem loss per year were positively related to increasing mean annual temperature (MAT) (figure7), and related in a unimodal fashion to mean annual precipitation (MAP), where mortality rates were highest between 2000 and 3000 mm values and lower in the warmer and wetter regions beyond that band respectively (Figures 7 and 8).

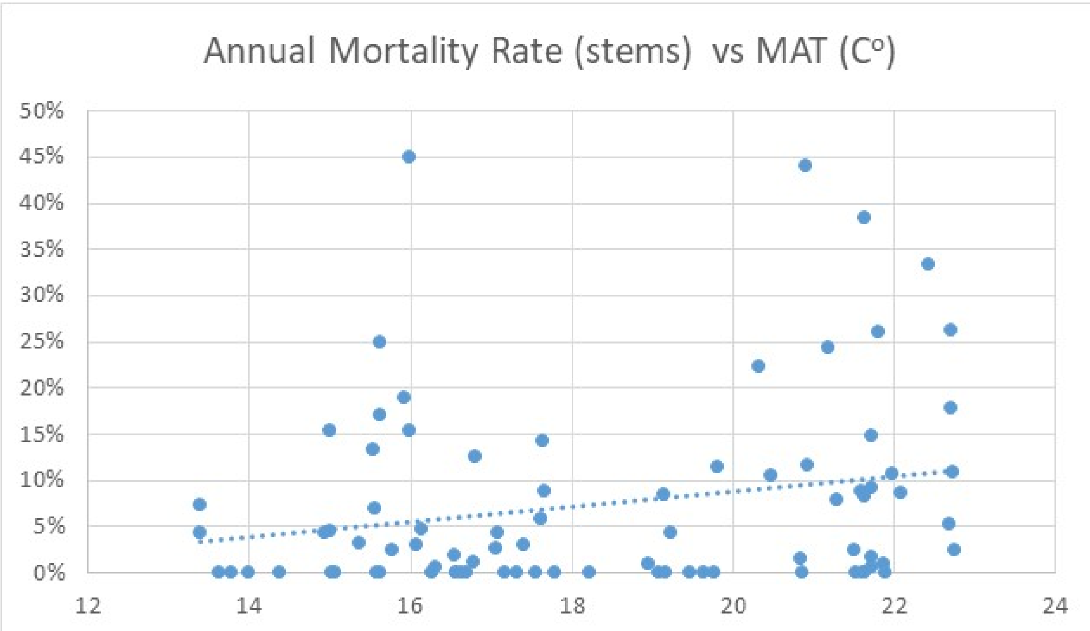

Figure 7. Relationship between annual ʻŌhiʻa mortality rates and mean annual temperature of each ROD mortality plot.

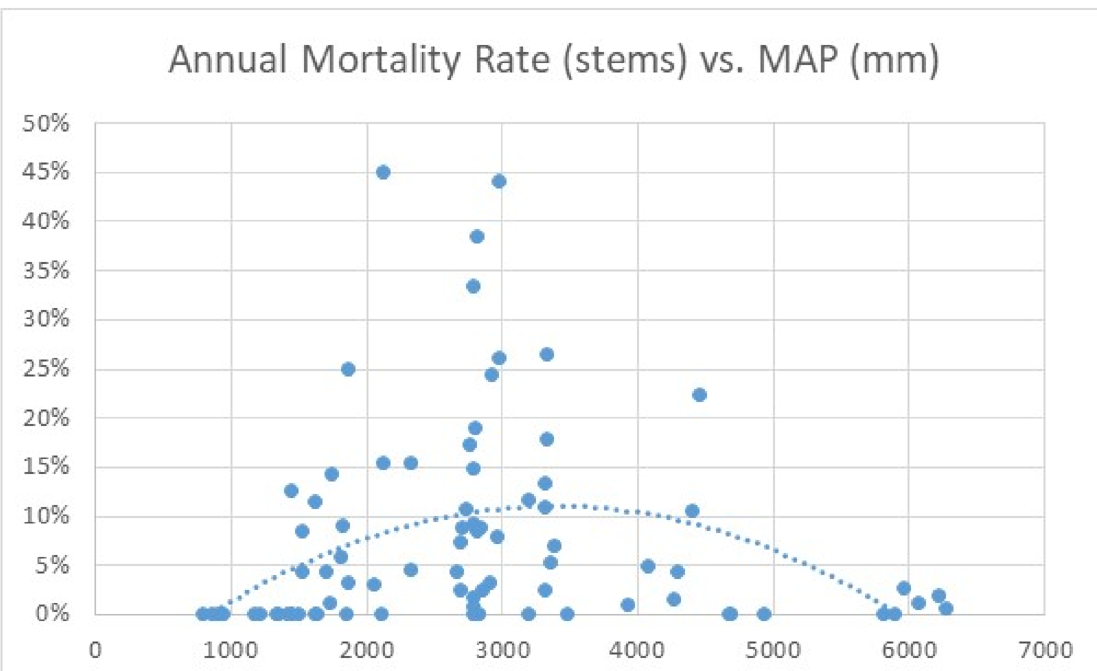

Figure 8. Relationship between annual ʻŌhiʻa mortality rates and mean annual precipitation of each ROD mortality plot.

Frequencies of ‘Ōhi‘a seedlings encountered within the forest plots was exceedingly low or zero for the majority of the plots measured; ‘Ōhi‘a seedlings were completely absent from 153 of the forest plots, or 86% of the total plots. In mortality plots where ‘Ōhi‘a seedlings were encountered, seedling densities averaged ca. 5000 seedlings ha-1 (Figure 9); for the most part, plots containing ‘Ōhi‘a seedlings were found in the upper elevations of ‘Ōhi‘a forest range (Figure 10).

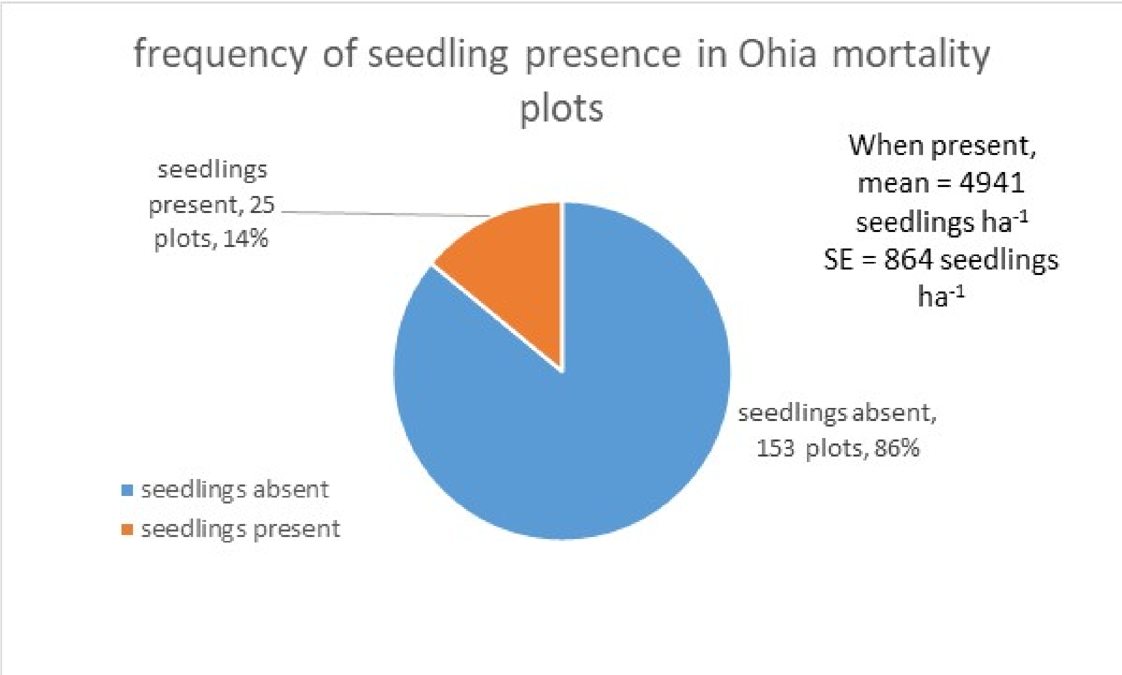

Figure 9. Frequency of the presence of ‘Ōhi‘a seedlings across all ROD mortality plots.

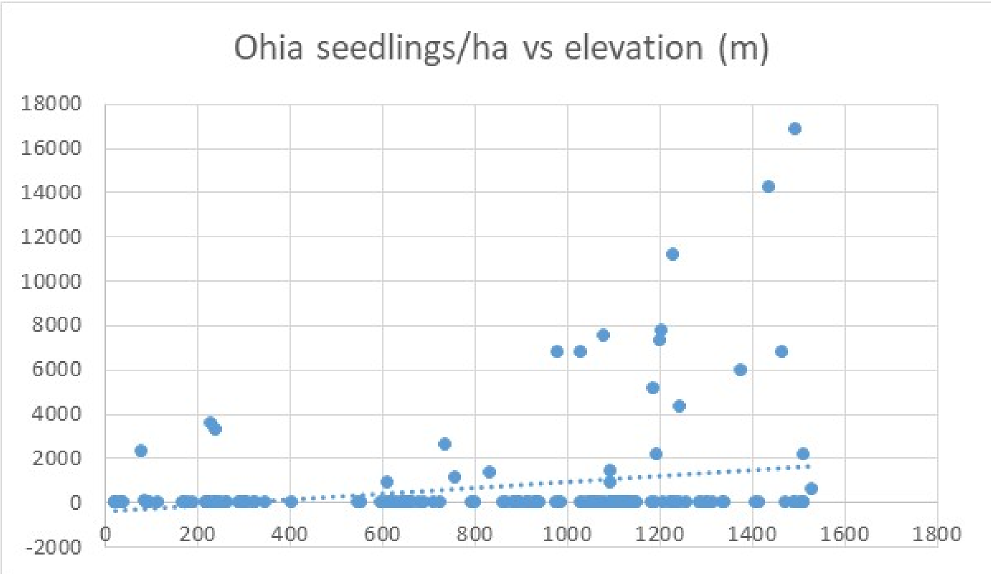

Figure 10. Relationship between the abundance of ‘Ōhi‘a seedlings encountered in ROD mortality plots (y-axis, seedlings per hectare) and elevation of each plot (x-axis in meters).

In addition, research to date has discerned landscape- and plot-scale patterns showing that areas that have been maintained in an ungulate-free state exhibit substantially lower levels of *Ceratocystis*-induced mortality compared to adjacent areas where ungulates are present and their disturbance effects on the forests – particularly with regard to wounding of ʻŌhiʻa – is apparent. This phenomenon can be seen in ROD mortality plots located in Kohala where annual ʻŌhiʻa mortality rates were significantly lower plots exhibiting low levels of pig activity relative to those of plots exhibiting higher levels of pig activity (Figure 11). The underlying mechanism involved is thought to be that ʻŌhiʻa forests are less likely to be wounded in ungulate free areas relative to areas of high ungulate density. As *Ceratocystis* is well-known to be a wound pathogen (i.e., the fungal spores require a fresh wound in order to infect a given host), suppression of wounds logically decreases the vulnerability of ʻŌhiʻa trees to infection and subsequent mortality, even in areas where inoculum concentrations are high. This is being demonstrated in additional sets of forest monitoring plots located within and outside fenced areas at several distinct locations on Hawaii Island. Further research is needed to look directly at the role of ungulates – and particularly pigs – in transporting and/or transmitting ROD.

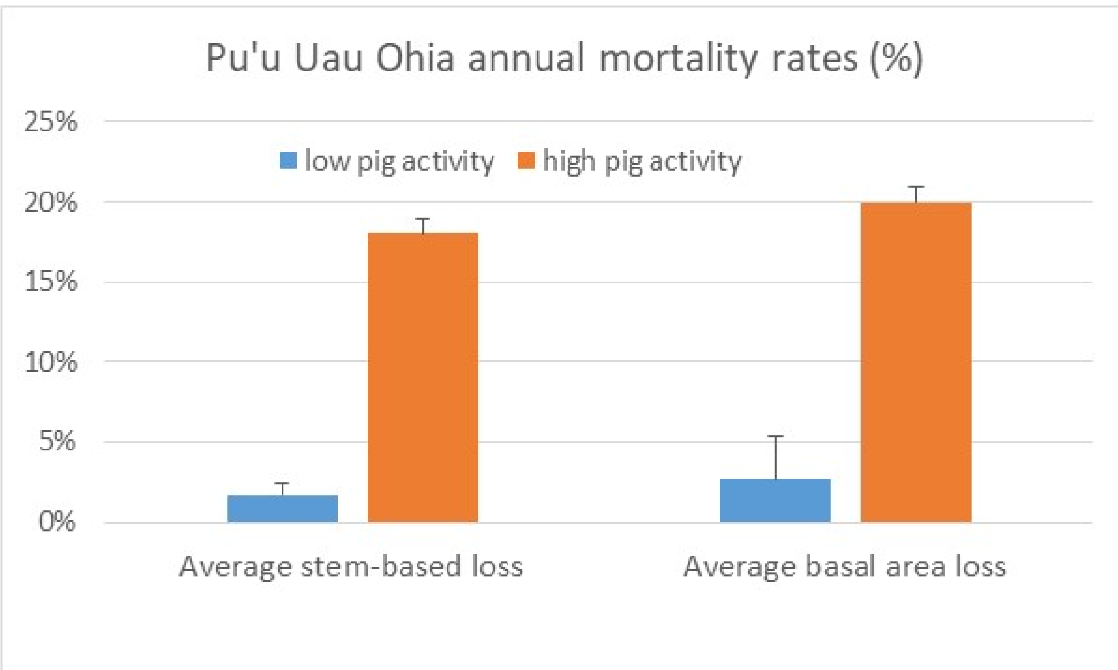

Figure 14. Mean and standard error values of annual ʻŌhiʻa mortality rates (y-axis, % values) in ROD mortality plots exhibiting low pig activity (blue bars) compared to ROD mortality plots exhibiting high pig activity (orange bars). Mortality comparisons are made on both an ʻŌhiʻa stem based mortality loss as well as on an ʻŌhiʻa basal area based mortality loss.