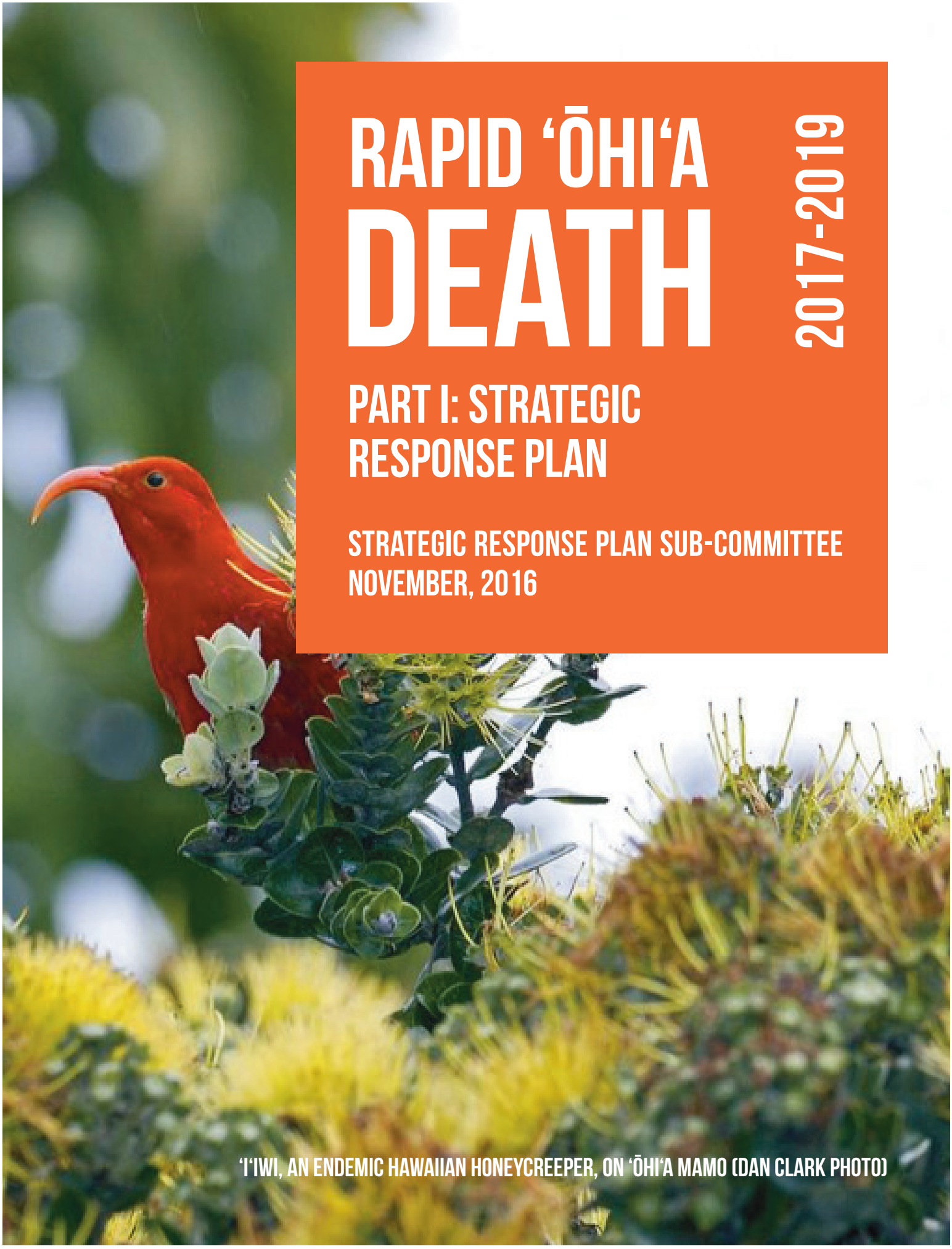
RAPID ʻŌHIʻA DEATH

2017-2019

PART I: STRATEGIC RESPONSE PLAN

STRATEGIC RESPONSE PLAN SUB-COMMITTEE
NOVEMBER, 2016



ʻIʻIWI, AN ENDEMIC HAWAIIAN HONEYCREEPER, ON ʻŌHIʻA MAMO (DAN CLARK PHOTO)

CONTENTS

ACRONYMS

CTAHR: College of Tropical Agriculture and Human Resources
DLNR: Department of Land and Natural Resources
DOI: Department of the Interior
EDRR: Early detection/Rapid response
HDOA: Hawaiʻi Department of Agriculture
PCSU: Pacific Cooperative Studies Unit
UH: University of Hawaiʻi
USDA: United States Department of Agriculture

RAPID ʻŌHIʻA DEATH

PART I: STRATEGIC RESPONSE PLAN FOR HAWAIʻI, 2017-2019

POINT OF CONTACT:

Robert D. Hauff

State Protection Forester
DLNR Division of Forestry & Wildlife
Tel. (808) 587-4174
Robert.D.Hauff@hawaii.gov

PRIMARY CONTRIBUTORS:

Phil Cannon (USDA Forest Service), Charles Chimera (UH Pacific Cooperative Studies Unit), J.B. Friday (UH College of Tropical Agriculture and Human Resources), Christian Giardina (USDA Forest Service), Thomas Harrington (Iowa State University), Rob Hauff (DLNR Division of Forestry and Wildlife), Flint Hughes (USDA Forest Service), Jim Jacobi (US Geological Survey), Lisa Keith (USDA Agricultural Research Service), Kealoha Kinney (USDA Forest Service), Lloyd Loope (Loope Environmental Consulting), Ric Lopez (USDA Forest Service), Christy Martin (UH PCSU Coordinating Group on Alien Pest Species), and Corie Yanger (UH College of Tropical Agriculture and Human Resources).

We greatly appreciate the major review by: Carter Atkinson, Joshua Atwood, Gordon Bennett, David Benitez, Susan Frankel, Curtis Ewing, Alan Holt, Jenny Juzwik, Teya Penniman, Evelyn Wight, and Mike Wingfield.

FOREWORD

Rapid ʻŌhiʻa Death (ROD) is an extremely serious threat to Hawaii's native forests. Mortality caused by the disease is unprecedented with respect to scale, rapidity, and potential impact. To date, this disease has only been found on ʻōhiʻa and is caused by an introduced fungal pathogen. ROD should not be confused with either ʻōhiʻa dieback, where groups of trees die over a period of a few years due to natural causes, or with *Puccinia* rust, an introduced disease that was first reported in Hawaiʻi in 2005 and affects new leaves and stems of ʻōhiʻa, rose apple, and other closely related plants. ROD has the potential to kill most ʻōhiʻa individuals in an infected forest. In the few years since ROD symptoms were detected in ʻōhiʻa trees in the Puna District of Hawaiʻi Island, the disease has already become well established in large areas of this district and has since spread to many more areas on Hawaiʻi Island.

As a disease, ROD is particularly problematic because it is caused by two distinct but closely related fungal pathogens within the genus *Ceratocystis*. While exhibiting different pathologies, apparent modes of spread, distributions, and introduction histories, both *Ceratocystis* species cause high rates of mortality in ʻōhiʻa forests, complicating planning and response. Given the importance of ʻōhiʻa to the ecology, hydrology, economy, and cultures of Hawaiʻi, as well as the high potential for further spread of ROD across Hawaiʻi Island and the rest of the State, this Strategic Response Plan (SRP) represents a call for rapid, coordinated, sustained, and large-scale impact management of this unprecedented threat. This SRP also reflects the need to transition from *emergency response* to a more sustainable and organized *strategic response*, and focuses on the following questions:

Locations where *Ceratocystis* is present and impacting ʻōhiʻa forests as of November 15, 2016. (Anya Tagawa image, after ROD Working Group map)

What do we currently know about ROD?

What do we need to know about the disease and how do we address the unknowns?

What do we need in order to manage this disease and its impacts?

To address these questions, the best available science and input from many people working on ROD have been used to craft this plan that documents what we have learned since the cause of ROD was identified in late 2014, and the major needs for the next three years. To date, agencies, institutions, and non-government organizations (NGOs) have contributed more than $2,000,000 in staff time and in-kind support, and have applied for and received another $2,159,950 in ROD funding from federal, state and private sources in 2015-2016.

This plan projects the additional needs of $3.6 million for 2017, and $3.2 each year for the next two years, 2018 and 2019, assuming that existing staff and agency in-kind support will continue at least at current levels. Public and private funds will continue to be sought to fund the priorities in this plan.

SITUATION OVERVIEW

The identification, pathology, distribution, and severity of Rapid 'Ōhi'a Death – This new disease is caused by two species of the fungal pathogen *Ceratocystis*, which has rapidly spread across the southern districts of Hawai'i Island and killed millions of 'ōhi'a trees (*Metrosideros polymorpha*). The disease currently impacts over 50,000 acres of 'ōhi'a forest, representing about 10% of all 'ōhi'a forest on Hawai'i Island. To infect a tree, the pathogen must enter through an open wound, after which it spreads into the trunk, stopping water transport. Although trees may be infected for many months before showing outward symptoms, once the first visible symptoms appear, death follows within a few weeks, earning the name "Rapid 'Ōhi'a Death". Initial results from ongoing research into the impacts of the disease have shown average annual mortality rates as high as 20% in 'ōhi'a forests where the disease is present, and nearly 100% mortality in areas where the disease has been present for several years. First detected in the Puna and South Hilo districts, ROD has spread to Ka'u and South Kona districts. There have been no confirmed cases of ROD in North Hilo, Hāmākua, and Kohala districts, nor have there been confirmed cases on any of the other Hawaiian Islands, as of November 2016.

An 'ōhi'a tree may be infected for many months before showing symptoms, but once the pathogen moves into and blocks the flow of water in the trunk, the tree crown turns yellowish (chlorotic) and then brown within days to weeks, with the entire tree dying soon after (J.B. Friday photo)

The 'ōhi'a tree is Hawai'i's most important native tree species, occurring as the dominant tree in at least 80% of Hawai'i's native forests and representing 50% of all forests in Hawai'i. Occupying nearly one million acres across the Hawaiian Islands, 'ōhi'a forests extend from sea level to 8,000 feet in elevation and from very dry areas to rainforests receiving over 300 inches of rain per year. 'Ōhi'a is often the first flowering plant to colonize fresh lava flows, and also flourishes on 4 million year old soils of Kaua'i. 'Ōhi'a forests protect the upper reaches of the State's critically important watersheds, which supply fresh water to downstream communities and agriculture. The State's most endangered native birds such as the 'akepa and Hawai'i creeper make their home in high elevation 'ōhi'a forests, along with hundreds of other native animals and plant species, many of which are rare, threatened, or critically endangered. Tens of thousands of Hawai'i Island residents live in or adjacent to 'ōhi'a forests, and over a million people a year visit the 'ōhi'a forests of Hawai'i Volcanoes National Park. 'Ōhi'a forests have been treasured by native Hawaiians for centuries, not only for practical uses but also in art, such as hula where 'ōhi'a is the *kinolau* (bodily manifestation) of important Hawaiian gods Kū, Laka, Kāne, and Pele.

Data gaps and knowledge voids – The origins and exact modes of entry into Hawai'i of the two *Ceratocystis* species that kill 'ōhi'a are currently unknown. DNA analyses of fungal samples from ROD-impacted trees do not match other *Ceratocystis* species catalogued in global databases. These two *Ceratocystis* species are in the process of being taxonomically described and named as new species and are currently being referred to as *Ceratocystis* Species A and *Ceratocystis* Species B. Both Species A and Species B likely were accidentally introduced to Hawai'i with imported plants or plant parts – high-

lighting the need for biosecurity measures focused on plant diseases to prevent additional importations. Such measures would also prevent further spread of this disease statewide and beyond. Analyses of DNA from thousands of fungal isolates suggests similarities with the Caribbean group of *Ceratocystis* (most similar to Species A) and the Asian group of *Ceratocystis* (most similar to Species B). There remains a critical need to definitively identify the genetic relationships of the Hawai'i species to other *Ceratocystis* species, in order to understand where these species are from, what host plant material they entered on, what additional plant species might be vulnerable to attack, and what additional biosecurity measures are needed to restrict entry of other host plant species.

In some areas like this forest in Puna, nearly all of the 'ōhi'a have died from ROD, and there are few if any 'ōhi'a seedlings emerging among the invasive plants in the understory (J.B. Friday photo)

There are several suspected vectors for the spread of ROD, although the relative importance of each is not known. The disease can be spread by people moving infected materials to ROD-free areas – for example the movement of infected 'ōhi'a logs for posts or firewood, or 'ōhi'a plants for landscaping or restoration. Certain *Ceratocystis* spore types are "sticky" and can be transported on cutting tools such as machetes and chainsaws, which can spread the disease when used on uninfected trees. *Ceratocystis* also produces highly durable spores that are long-lived under a variety of environmental conditions. Researchers also suspect that the disease is spread by wind and movement of infected sawdust called frass that is created when wood boring beetles bore into infected, dying, or dead 'ōhi'a trees. The resulting wood frass can contain fungal spores that can be spread by wind. Initial wind transport modeling suggests that infected frass can be transported for many miles, although it is not clear how much of the inoculum is needed to infect a tree. Following transport, *Ceratocystis*-laden dust or frass can land on 'ōhi'a where it may enter an 'ōhi'a tree through aboveground wounds, or become incorporated within surrounding soil where it may enter trees through the root system. *Ceratocystis* has been detected in soil near infected trees, and this soil can be spread by shoes and vehicles that trap and transport spores to new locations.

The fungus can remain viable for at least a year in dead wood, although it is not yet clear how long after a tree dies or is harvested before the material no longer contains living, infective spores. Kiln-drying wood at temperatures greater than 130^{O}F kills the fungus. Moving any 'ōhi'a wood product that has not been thoroughly kiln-dried may pose a risk. The *Ceratocystis* fungus and resulting spores can also persist in soils, and so transport of soils or live plants in unsterile media or soil should be avoided. Potted 'ōhi'a plants also pose a risk and should not be moved into disease free areas. To this end, the Hawai'i Department of Agriculture (HDOA) instituted an interim rule in August 2015, which bans the movement of Myrtaceae plants, plant parts, and soil from Hawai'i Island to other islands in the State without a permit. In 2016, HDOA went through formal rulemaking to make the interim rule permanent. To date, there are no ROD-related interstate or foreign export restrictions for the protection of related *Metrosideros* species outside of Hawai'i including Samoa, Fiji, New Caledonia, and New Zealand. Current research efforts urgently seek to understand how environmental conditions may be associated with stands of ōhi'a impacted by ROD, with a focus on geology, soil types, climate, and

topography. Field plots and remote sensing are being used to determine how the disease progresses in infected forests and spreads to new areas, providing information required for rapid response and silvicultural recommendations for managing the disease. While many thousands of acres of higher elevation native forests in Hawai'i Island are relatively healthy, native forests growing below about 3,000 feet in elevation are often altered by a diversity of invasive plant species. In such areas, where ROD has killed or is killing 'ōhi'a overstory trees, non-native plants dominate the understory, reducing their watershed, conservation and cultural value. For these systems, additional effort must be directed at dealing with multiple threats.

Preliminary systemic fungistatic applications to *Ceratocystis*-infected 'ōhi'a saplings in the greenhouse show promise of preventing death from *Ceratocystis*. A fungistatic is distinct from a fungicide in that an infected tree is not cured of the fungus, rather fungal growth is arrested. Development of such a tool and its application will help private landowners who wish to maintain individual ōhi'a trees on their land, or for landowners who wish to maintain heritage 'ōhi'a trees or 'ōhi'a corridors. Fungistatics likely will need to be reapplied to the same tree on a somewhat regular basis. Research is underway to understand how long a single application remains effective, and the opportunities and limitations of this method. For other species and associated wilt diseases found elsewhere, a single application has been shown prevent the advancement of disease symptoms for one to two years.

Metrosideros ('ōhi'a) is a highly variable genus with eight named varieties of *M. polymorpha* and four other species of *Metrosideros* found on the older islands of Hawai'i. Given this genetic diversity, research is underway and will be expanded to determine whether or not disease resistance exists in wild populations of 'ōhi'a at genotype, population, and species levels. As a precautionary action, a statewide effort is underway to collect 'ōhi'a seed from populations throughout the main Hawaiian Islands to preserve 'ōhi'a's wide genetic diversity.

Current status and future need of the response – In the past two years, the Hawai'i conservation community has made extensive progress in understanding and addressing the ROD crisis. A multi-agency ROD Working Group ROD was established in 2015 to coordinate research, management, and outreach. The ROD Working Group has facilitated many important advances with respect to ROD, including: definitively identifying two species of *Ceratocyctis* as the cause of ROD; developing and implementing aerial surveillance and ground-based ROD detection methods; careful mapping of the current extent of ROD affected stands and isolated outbreaks; building a statewide ROD prevention program that reaches many thousands of Hawaii's citizens every day; providing the science needed to establish Hawai'i Department of Agriculture's quarantine rule restricting the movement of 'ōhi'a material and soil out of Hawai'i Island; and identifying the potential vectors that most likely cause spread of the disease. Continued investments are required to prevent further spread of the disease across Hawai'i Island and the state. Despite considerable progress in determining the identity, pathology, distribution, and seriousness of this disease - information that forms the basis for this SRP- additional research is necessary before a comprehensive strategic response plan focused on management actions can be developed and implemented. This SRP focuses on knowledge gaps and laying the foundation for an adaptable strategic response plan to address critical research needs and to provide management recommendations that can be implemented immediately, or in the very near future. This document provides the basis for enhanced partner coordination and collaboration in addressing this ecological crisis, and for building a framework for effective ROD disease management and ecosystem restoration.

GOAL AND OBJECTIVES

The goal of this SRP is ***to provide a roadmap that conveys the current situation and known needs for the next three years for understanding, and where possible, addressing ROD.*** This SRP presents seven strategic objectives in the areas of containment, early detection, rapid response, outreach, and restoration:

Nearly a million acres of ʻōhiʻa statewide provide habitat, shelter, and food for many species, including this endangered Hawaiian tree snail on Oʻahu which eats the mold that grows on the leaves. (Nate Yuen photo)

Objective 1. To understand and share the biocultural significance of ʻōhiʻa through this SRP; engage and learn from diverse partners representing culturally based ownerships in Hawaiʻi; and embrace culturally-based approaches for addressing ROD;

Objective 2. To develop a robust and efficient research plan for addressing high priority questions regarding: 1) *Ceratocystis* genetics, etiology and epidemiology of the disease; 2) the roles of people, insects, and wind as disease vectors; 3) detection of infected trees and treatment of infected sites; and 4) opportunities for restoring impacted ecosystems;

Objective 3. To create a sustainable, coordinated, and efficient response to the disease that: 1) limits disease spread from affected districts of Hawaiʻi Island to unaffected areas of Hawaiʻi Island and prevents spread to other islands through a coordinated early detection and rapid response program; 2) develops robust containment and management of both disease infestations as well as new occurrences in otherwise disease-free areas; 3) deploys technologically advanced surveillance, monitoring, and early detection approaches; 4) monitors disease impacted areas, their long-term response to the pathogen, and projects future impacts; and 5) develops restoration plans for the range of ʻōhiʻa forest types and ownerships so that managers have access to next steps for addressing impacts of the disease;

Objective 4. To provide the science and recommendations for guidelines, best management practices, or policies to manage disease spread over the long term;

Objective 5. To develop a public outreach and engagement strategy that best engages Hawaiʻi's citizens and conservation organizations to address this disease;

Objective 6. To describe critical roles and responsibilities across agencies and organizations, including how roles and responsibilities are to be coordinated today and into the future;

Objective 7. To provide a synthesis of proposed activities and actions, and a detailed and transparent budget so the public, decision makers, agency leadership, and managers can clearly understand what is required to address the ROD threat.

REQUIREMENT	
2017	$120,000
2018	$120,000
2019	$120,000

CULTURAL SIGNIFICANCE AND ENGAGEMENT

Among the many plant and animal species native to Hawai'i, 'ōhi'a holds tremendous cultural significance to native Hawaiians. This species is a foundation for nearly all aspects of native Hawaiian engagement with the natural world. Through chant and story, native Hawaiians have maintained an enormous repository of information on 'ōhi'a, information that provides a clearly articulated understanding of the many ecological, biogeochemical, and hydrological linkages that 'ōhi'a provides to Hawai'i. In contrast to Western knowledge systems, which have developed complementary understanding of 'ōhi'a's many bio-physical roles and ecosystem services, native Hawaiian knowledge systems also integrate understanding of 'ōhi'a's many and complex social, psychological and spiritual linkages between person and species. A critical distinction between Western and native Hawaiian perspectives is that 'ōhi'a is embraced as a revered deity and respected family member, and this reverence and respect forms the bonds of a sacred relationship between 'ōhi'a and the Hawaiian people. Native Hawaiian organizations and institutions that serve native Hawaiians own, manage, or otherwise interact with a very large fraction of Hawai'i's native 'ōhi'a forest. Approximately 17% of all land on Hawai'i island falls under the responsibility of native Hawaiian serving organizations, including Bishop Estate's Kamehameha Schools, the Department of Hawaiian Homelands, and the Office of Hawaiian affairs: 297,000 acres, 116,963 acres and 25,856 acres, respectively. These organizations and institutions are increasingly approaching management through the lens of sacred relationship to place. Consequently, native Hawaiians and especially practitioner communities are deeply concerned about ROD impacts on 'ōhi'a, the forests and biophysical linkages created by 'ōhi'a, and the sacred familial connections between people and 'ōhi'a. Adapting traditional practices of forest gathering and ceremony to the presence and management of ROD will require ROD managers and researchers to work conjointly with native Hawaiian and local communities to develop culturally appropriate strategies and approaches.

In the Hawaiian language there is an abundance of words to describe rain, many of which incorporate the word lehua, reflecting the strong cultural significance and connection between the native Hawaiians and 'ōhi'a. (Nate Yuen photo)

The SRP recommends the creation of a cultural engagement team that is comprised of native Hawaiians, local residents, and forest gathering practitioners as well as members of the ROD working group, to be charged with developing guiding protocols and cultural considerations for ROD management and strategic planning. Integrating traditional ways of knowing is important because the success and reach of ROD management activities is largely dependent on native Hawaiian and local community investment in and approval of ROD management prescriptions.

Responding to environmental change is not new to Polynesian and other island cultures. There is an important collective history of experience embodied in ancient Hawaiian knowledge and practices that can inform how we respond and address ROD from both a cultural and ecological perspective. The SRP recommends that Native Hawaiian organizations lead local and native Hawaiian communities in a series of workshops designed to explore the wealth of biocultural knowledge and practices captured in oli (chants), mele (song), and mo'olelo (stories) and how this knowledge may be used to nurture individual and collective responsibility to participate in and take responsibility for managing ROD. Data collected from the workshops will be synthesized and used to construct the scaffolding needed to forge a new Kānāwai (law or ethic, but literally meaning water and responsibility Hawaiians had for controlling and conserving water). A Kānāwai-based approach represents a culturally appropriate response when there is a need to guide the behavior of people for the betterment of all. To this end, inclusive outreach and dialog will be initiated with native Hawaiian, local communities, and government agencies statewide to reach consensus about the meaning, mechanics, and implications of the Kānāwai for ROD. As a result of this work, this team will produce a new Kānāwai for ROD based on traditional, local, and scientific knowledge. The Kānāwai for ROD will help create a systemic sense of responsibility in our local communities and government agencies to participate in managing and preventing ROD. The Kānāwai will be supported by a guiding framework document that details the cultural, scientific, and legislative factors considered in the proposed Kānāwai for ROD management.

From early Hawai'i to the present day, flowers, seed capsules and liko (new leaves) have been used for lei. (J.B. Friday photo)

To achieve this work, the Plan recommends funding for travel and staffing to engage and instruct ROD Working Group partners in the research, response, and outreach aspects of the disease ($120,000 each year for three years).

REQUIREMENT	
2017	$1.6 M
2018	$1.4 M
2019	$1.4 M

RESEARCH TO INFORM RESPONSE

Research required to adequately manage ROD falls into five main categories: 1) understanding the epidemiology and pathology of ROD; 2) determining modes of dispersal; 3) quantifying ROD impacts on the forest; 4) mapping the extent and dynamics of ROD on Hawai'i Island; and 5) developing prescriptions to treat disease impacted areas. Two collaborative ROD Working Group Teams have been meeting on a regular basis to identify ROD science needs and to define a framework for making urgently needed progress in these areas.

The development of a molecular detection technique for *Ceratocystis* Species A and B reduced sample testing time from two weeks to 24 hours. A rapid field test is currently being developed. (USDA ARS photo)

Detecting ROD and understanding its pathology – There is an urgent need for information about the life history, pathology, hosts, and host range of *Ceratocystis* Species A and Species B, the genetic basis of *Ceratocystis* host plant specificity including the mechanisms by which *Ceratocystis* overcomes host defenses, and the genetics of host plant resistance. Further research is needed to understand genetic versus environmental factors of ROD disease susceptibility and disease progression in wild populations of 'ōhi'a. Finally, there is a critical need for rapid, accurate, and reproducible methods for detecting and diagnosing *Ceratocystis* Species A and B in samples of wood, water, soil, air, and insect frass, both in the field and laboratory. This information will lead to 1) a better understanding of how plant and pathogen genetics affect ROD pathology and virulence, and how they interact with the environmental factors described above; 2) precisely defined temperature ranges for *Ceratocystis* pathogenicity and virulence; 3) information about *Ceratocystis* spore viability in 'ōhi'a wood and in nursery seedlings under different environmental conditions to support effective quarantine actions; 4) information on how the pathogen enters into otherwise healthy trees; and 5) development of molecular based approaches to detecting and confirming disease presence in the field. Such diagnostic tests will be integral for epidemiological studies, facilitating HDOA quarantine inspections, and early detection and rapid response efforts. Fundamental epidemiology research, including understanding genetic versus environmental factors of ROD disease susceptibility and resistance, is needed for varieties of *Metrosideros polymorpha*. Personnel and resources required for this work include three post-doc and two technician salaries, lab and greenhouse materials and supplies, and growth chambers ($661,000 for 2017 and $520,000 each year for 2018 and 2019).

Understanding disease dispersal – There is an urgent need to understand how ROD is spread and whether this information can be used to control disease transmission from ROD infected forests to unaffected sites. This understanding is central to containing the disease and developing the most effective rapid response protocols. To this end, research is needed to determine: 1) potential insect vectors and the environmental factors correlated with their ecological activities, dispersal, and disease transmission; 2) differences in dust and frass created by different species of wood boring beetles, inoculum production rates, and *Ceratocystis* presence across sites that may contribute to short and long

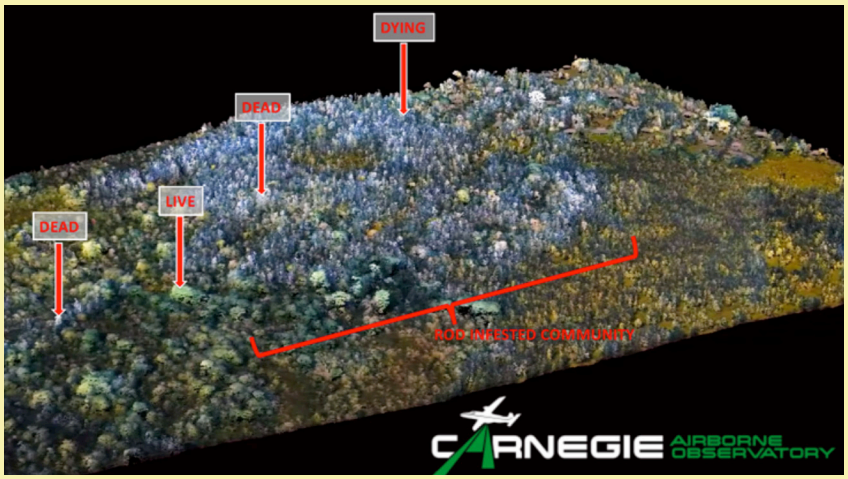
distance dispersal of fungal spores; 3) whether birds or other animals move infective spores; 4) whether cutting, covering, or chemically treating trees are effective means to reduce beetle colonization of dead or dying trees and to reduce dust and frass production; 5) environmental factors that affect dispersal by wind and water; 6) what the relative risks of human-caused spread are (e.g., hiking, off-road vehicles, etc.); 7) whether fencing and ungulate removal or other forest conservation measures result in reduced numbers of ROD infected trees; and 8) what type of monitoring approaches are best to evaluate the effectiveness of ROD containment actions. Personnel and resources required for this research include: salaries for senior researcher, graduate student, two field and two lab technicians, equipment and supplies ($370,000 each year for 2017, 2018, and 2019).

Understanding the impact of ROD on ʻōhiʻa forests – There is a critical need to understand how ROD affects the structure and composition of ʻōhiʻa forests, determine ROD related rates of mortality in various forested areas, document what happens to these ROD affected forests over time, and project the impact of ROD to ʻōhiʻa at larger scales. A network of ROD research plots has been established in the past two years and is being expanded to encompass the range of ROD impacted ʻōhiʻa forest types across Hawaiʻi Island. These plots are sampled regularly to quantify extent and patterns of ROD mortality, determine whether *Ceratocystis* Species A and/or B are responsible for tree mortality; identify physical (e.g., lava substrate and age, climate), biological (e.g., forest size, age and composition), and hydrological (e.g., drainage, water holding capacity) factors that may affect disease distribution, and determine post-ROD forest succession across varied landscapes. Annual re-measurement of these plots and variables provides fine scale understanding of ʻōhiʻa mortality, information for developing treatment and restoration actions, and field based data to inform aerial surveys and remote sensing based modeling. The personnel and resources required include two technicians ($120,000 each year for 2017, 2018, and 2019).

Beetles like this ambrosia beetle (*Xyleborinus saxesenii*) have been found boring into sick and dead ʻōhiʻa, producing sawdust (frass) that is contaminated with *Ceratocystis* spores. Research is progressing on the role of insects and wind in the spread of the disease. (Curtis Ewing photo)

Spatial dynamics of the threat – There is a continued need for information about where ROD occurs, where it is spreading, and why some ʻōhiʻa stands appear to be impacted more than others. Significant investment has already been made into ROD detection capability through remotely operated vehicles, plane and helicopter-based surveys to map and monitor ROD impacted areas. (The aerial detection surveys described in the Response section will be closely coordinated with this work.) This approach integrates several technologies and uses new imaging methods to precisely map and monitor how tree-by-tree ʻōhiʻa condition is changing over time on Hawaiʻi Island. Remote sensing results will drive spatial analyses that model patterns of ROD mortality, helping understand how environmental factors such as temperature, rainfall, and soils affect the distribution, spread, and virulence of ROD. This will support efforts to target the most vulnerable habitat types across Hawaiʻi for protection. Given the rapid spread of the disease, annual re-mapping of Hawaiʻi Island is critical for informing rapid response and containment efforts. Personnel and resources required for this work include remote sensing flights, a post-doc, and partial support for technicians and geospatial analysts ($425,000 each year for 2017, 2018, and 2019).

Restoring ROD-impacted forests - There will be a critical need to develop condition specific and cost-effective strategies for restoring ROD impacted forests, and to create tools to support decision makers and managers in their efforts to prioritize ROD treatment and restoration projects on the landscape. Forests of ʻōhiʻa naturally occur across enormous gradients in climate and soils and are associated with diverse species assemblages. Additional variation is driven by diverse ownerships on which ʻōhiʻa occurs. ROD is already affecting ʻōhiʻa across widely ranging sites – from young lava flows in warm and wet areas of Puna to older lava flows in cooler and drier areas of Kaʻu to older well developed soils in cooler and wetter areas of North Hilo. Restoration actions and decision support for ROD containment and post-containment management restoration need to be developed that are specific to site climate and soils, existing and nearby assemblages of native and non-native species, land ownership and landowner objectives, cultural considerations, access to planting materials, funding sources, proximity to weed species, extent of mortality caused by ROD to ʻōhiʻa, and other ecological and social considerations. Because even a greatly expanded investment into restoration is unlikely to match what is already an enormous need, implementation of restoration actions must be highly cost-effective and strategic. These activities will be on-going and carried out with existing staff and agency programs until a more structured and informed restoration plan is developed.



By conducting test flights with the Carnegie Airborne Observatory in 2016, aerial surveys measured and mapped biologically important chemicals in forest canopies in three dimensions, with the goal of developing ROD detection capability to track and study the spread of ROD for patterns, and possibly detect it earlier than by other means. (Carnegie Airborne Observatory image)

REQUIREMENT

2017	$1.3 M
2018	$1 M
2019	$1 M

RESPONSE TO THREAT

This Plan outlines five critical components to a comprehensive ROD response: (1) Actions required to limit spread; (2) early detection surveillance for disease outbreaks; (3) rapid response to new outbreaks; (4) containment actions required to control the disease; and (5) restoration of ROD-impacted forest areas.

Preventing the spread of ROD – The spread of this disease occurs in several ways: through people moving infected material, and by environmental means such as insects, or by wind and water transport. Research is underway to understand whether and how insects and wind spread the disease. Therefore, this section emphasizes the need to better understand and prevent movement of disease inoculum by people. *Ceratocystis* spp. are known to be spread via movement of infected agricultural products and plant materials, and sometimes the type of infected plant material is not related to what it infects once moved. The pathway for introduction is also covered under the Research section, and preventing additional strains of *Ceratocystis* from coming into Hawai'i is a high priority. Once likely plant vectors are identified, restricting their importation is recommended. The public plays an essential role in limiting the further spread of ROD within Hawai'i Island and preventing movement of the disease to other Hawaiian Islands, but effective engagement will require enhanced coordination among ROD partners, local organizations, businesses and communities. In response to current science information and strong community support, HDOA moved quickly to enact interim rules to restrict the movement of this disease from Hawai'i Island to other islands in 2015, and rulemaking is nearly complete to make the rule permanent. This will result in a permanent rule to prohibit, except by permit, the export of all *Metrosideros* species plants, plant parts, wood, and soil from Hawai`i Island. If *Ceratocystis* Species A or B is detected on other islands in the State, it is strongly urged that the quarantine be expanded to protect the other islands. During the year-long interim 'ōhi'a quarantine rule, multiple shipments of infected material were intercepted and prevented from leaving Hawai'i Island – shipments that would have introduced the disease to other Hawaiian Islands had they been allowed to reach their respective destinations. The new Interagency Biosecurity Plan reflects the needs for interisland biosecurity work, including inspection work related to ROD. Notably, before the HDOA quarantine rule was in place, the locally-owned shipping company Young Brothers, Inc. voluntarily halted transport of

Hawaii Department of Agriculture continues to work closely with the ROD researchers to identify and test effective quarantine treatments that would be used to create permit conditions for safe movement of regulated products like wood and soil from Hawaii Island. (HDOA photo)

all ʻōhiʻa material out of Hawaiʻi Island. In contrast, no restrictions exist regarding movement of ʻōhiʻa within Hawaiʻi Island, and so prevention efforts on Hawaiʻi Island rely entirely on large-scale public awareness and voluntary compliance.

To continue limiting the spread of ROD, this SRP recommends a greatly expanded public outreach effort statewide, with details being covered in the following Outreach and Engagement section, and expanded funding via the Interagency Biosecurity Plan to support: 1) HDOA-Plant Quarantine inspection personnel and equipment; 2) pre-screening of plant materials imported into Hawaiʻi to prevent additional strains or species of *Ceratocystis* from entering Hawaiʻi, while also carefully monitoring plant material and media/soils being exported from Hawaiʻi Island; 3) construction of additional decontamination stations on Hawaiʻi Island in 2017, with annual maintenance support ($250,000 in 2017 and $50,000 each in 2018 and 2019). A discovery of ROD elsewhere in the state besides Hawaiʻi Island would change projected costs.

Surveillance, monitoring, and early detection – The distribution of ROD impacted forests is currently restricted to the southern districts of Puna, Hilo, Kau, and Kona on Hawaiʻi Island. Effective disease management, particularly rapid response, requires early detection of ROD infected trees in otherwise uninfected areas. This calls for timely access to accurate and up-to-date information regarding the location of newly symptomatic trees that can only be achieved through regular surveys and prompt sampling of suspect trees. Therefore, this SRP recommends: continued mapping of outbreaks and tracking disease movement via aerial surveys; conducting follow-up ground surveys to verify ROD presence; responding to citizen reports of disease to strengthen early detection in urban and residential areas; and structured sharing of data to coordinate monitoring and distribution of information. Aerial surveys using the Digital Mobile Sketch Mapping (DMSM) platform from helicopters are ideally suited to early ROD detection, especially in very remote areas, and should continue on a quarterly schedule for the northern portion of Hawaiʻi Island and twice per year statewide. Follow-up ground sampling of suspicious trees is required to identify and contain ROD occurrences. This SRP also recommends three detection and diagnostic investments: 1) a laboratory (or additional support for an existing laboratory) to help with ROD detection and identification work by processing and storing ROD infected samples and associated records while identifying new non-native pathogens; 2) production of field kits to test for the presence of the pathogen causing ROD in real-time, thereby reducing time between ROD detection and containment, and saving travel and labor costs; and 3) exploration of feasibility of a canine detector program.

Aerial surveys are being conducted on each island via helicopter. Dead ʻōhiʻa like this one on Maui are mapped and a ground crew hikes in to take samples. To date, none of the trees sampled outside of Hawaii Island have been positive for *Ceratocystis* Species A or B. (DLNR DOFAW photo)

These investments will allow for early detection of and rapid response to new ROD outbreaks; provide up-to-date maps of disease distribution and progression; and inform management decisions. The personnel and resources required for this work include additional funding for aerial surveys, ground crews, laboratory support, and data management ($525,000 each year for 2017, 2018, and 2010).

Rapid response to isolated ROD outbreaks – Aggressively treating localized ROD outbreaks in otherwise healthy forests is strongly recommended. Containment of fungal pathogens capable of being spread by wind, insect, and other vectors is difficult at best. However, careful and thorough implementation of sanitation practices, successfully implemented elsewhere in the world, will help prevent the spread of ROD. Complete eradication of *Ceratocystis* from even limited areas on Hawai'i Island is unlikely, but new ROD outbreaks may be effectively neutralized if detected and treated quickly and aggressively. Current ROD rapid response concepts are based on knowledge of *Ceratocystis* biology and rapid response work with other plant species and fungal diseases where the use of sanitation practices have proven effective in managing local epidemics. This SRP proposes that best management practices for ROD rapid response need to be implemented, monitored, assessed, and when needed, refined – all with the goal of arresting ROD spread into uninfected areas. To achieve containment of the disease, ROD outbreaks must be neutralized *in the very earliest stages of infestation.* Given the current distribution of ROD impacted forests, the urgency of implementing rapid response cannot be overstated.

The Early Detection and Rapid Response (EDRR) Team of the ROD Working Group provides a strong starting point for understanding requirements to implement, assess, and refine methods that promptly identify and control ROD outbreaks in the early stages of infestation. An EDRR Advisory Team is being formed to serve this role on Hawai'i Island, and will serve as a model for establishing similar teams on each of the main islands. High value 'ōhi'a forests of north Hawai'i Island and neighbor islands will be the focus of EDRR efforts. Currently, best management practices are being developed, and so in the early stages of EDRR, the most conservative removal strategies will be deployed until it is clear less stringent methods can be substituted.

Using best management practices, EDRR teams will quickly respond to and attempt to contain incipient ROD outbreaks before they become strongly established. Combined with follow up monitoring, these efforts will provide critical information for adapting methods and preventing the spread of ROD to north Hawai'i and neighbor islands. The personnel and resources required for this work include additional funding for aerial surveys, ground crews, and data management. Funds for this work are being provided by the DOI Service First grant, with some functions and costs shared from Surveillance and Containment budgets.

The scattered nature of infected trees and the wide extent of ROD on Hawai'i Island makes aerial surveys and new mapping technologies important tools. (Tom Harrington photo)

Containment of ROD-infected areas – ROD containment must happen at two scales. On a broad scale, the primary goal is to prevent ROD from moving into the northern districts of Hawai'i Island by containing ROD to Hawai'i Island's southern districts. On a finer scale, new ROD occurrences outside of currently impacted zones need to be contained *and* neutralized. Tools to completely eradicate the ROD fungus across the landscape are not available. Thus, it is important to develop and deploy methods to control initial outbreaks outside of heavily affected areas. Although methods have not yet been thoroughly evaluated, forest managers need to proceed with containment practices based on the best available science, anticipating that practices may need to be adjusted in light of new information about the disease and its spread.

The species name for 'ōhi'a is *"polymorpha"*, meaning "many forms", lending hope that there may be varieties of 'ōhi'a that are resistant to infection or that may survive infection by *Ceratocystis*. These 'ōhi'a seedlings are *Metrosideros polymorpha* var. *glaberrima* from the Waianae Mountains on O'ahu (Marian Chau photo)

The objective of containment treatments is to interrupt the disease-insect cycle and limit the amount of inoculum (fungal spores) being released into the environment. Before any management is carried out, sites should be selected based on: how recently mortality has occurred; location with respect to wind exposure; proximity to healthy forests and direction of prevailing winds; and levels of insect activity. Samples also need to be taken to ensure presence of the ROD pathogen. Site characteristics may require adjustments to treatment protocols. Based on this site assessment, a treatment plan with control prescriptions should be developed, and may include: felling of large dead trees that attract beetles and are exposed to winds; suppression of beetles boring in diseased wood, perhaps using physical (covering), chemical (pest management) and/or biological (decay fungus additions) approaches. Sanitation protocols should be strictly followed, and tree felling should occur on moist, low-wind days taking care to avoid wounding healthy trees which could lead to disease infection. Sites managed with the goal of controlling ROD spread from a newly affected site need to be monitored to determine whether operations are effective. Monitoring should include: sampling for beetle boring activity and resultant insect frass production; mapping disease spread over time through remote sensing; and follow-up, on-site inspections for tree mortality that may require additional felling. Additional information requirements (see Research section) include understanding effective ways to detect the pathogen in living trees; knowledge of how long spores stay viable in dead trees and how long the trees remain suitable for beetle activity; ability to detect meaningful levels of inoculum in the environment; understanding how and where insect frass is dispersed; and determining the role of insects in directly moving the disease from tree to tree. Personnel and resources required for this work include additional for ground crews, vehicle, helicopter transport, supplies and decontamination stations ($358,000 in 2017, and $290,000 in each 2018 and 2019).

Restoration of ROD-impacted areas – As with management of any threat, impact prevention is a much more cost-effective strategy than the restoration of already impacted areas. This SRP recognizes the need to prioritize rapid response and containment over less urgent activities. However, the current and projected loss of ʻōhiʻa is significant and has resounding impacts that must also be addressed.

ʻŌhiʻa growing near Halemaʻumaʻu Crater in the Kaʻu Desert, where wind, sulfur dioxide gas, and lack of water and soil are a testament to the resilience of *Metrosideros polymorpha*. (Nate Yuen photo)

It is not yet known if there are varieties of ʻōhiʻa that are resistant to ROD. Although work is underway to identify resistance within ʻōhiʻa, restoration actions in the three-year window of this SRP should rely on replanting ROD impacted areas with plants other than ʻōhiʻa. This SRP recommends a geospatial-approach combined with best available knowledge to develop preliminary restoration strategies that are specific to a given site and reflect consideration including: vegetation composition of the remaining stand; desired future condition; habitat and wildlife considerations; adjacency of problematic non-native or desirable native species; landowner/manager support and participation; cost of proposed actions, and other considerations. Currently, sources of native species for out planting are limited, and so part of the landscape restoration solution will need to include an expansion of nursery capacity. For some ownerships, non-native species solutions may be selected to restore forest cover and keep out invasive species.

An important tool in preventing the extinction of threatened flora is the gathering and storage of seeds as a "genetic safety net." This approach is commonly referred to as seed banking, and is especially important when the source of the threat is poorly understood or cannot yet be mitigated, as is the case with ROD. Lyon Arboretum has taken the lead in raising funds via a crowdsourcing campaign called ʻŌhiʻa Love, and has begun collecting and storing a number of ʻōhiʻa seeds in their Hawaiian Rare Plant Program Seed Conservation Laboratory. These seeds will provide an important tool for preserving genetic diversity of ʻōhiʻa, and will also enable researchers to test the many varieties for resistance to the ROD pathogen. Expansion of a native Hawaiian seed saving network to each county with other University or conservation institutions could also ensure the long-term protection and availability of seeds for restoration work. The personnel and resources required for this work include one restoration specialist and seed banking personnel, supplies, and travel ($150,000 for each year, 2017, 2018, and 2019).

REQUIREMENT

2017	$586,000
2018	$540,000
2019	$540,000

PUBLIC OUTREACH AND ENGAGEMENT

A tremendous amount of public outreach has been done since the cause of ROD was identified. An ad hoc team of outreach staff from agencies and NGOs assisted the one full-time ROD extension staff to craft public messages to reduce the chances of the public spreading the ROD pathogens. Radio and television public service announcements, print materials, and articles were deployed, as well as workshops and outreach talks with communities. Media campaigns provided guidance and encouragement to forest users to decontaminate footwear, equipment, and vehicles, and signage with decontamination stations were installed at select public trailheads. More than 60 ROD information sessions and workshops, landowner visits, and school presentations have been held on Hawai'i Island, and dozens more have been held on other islands. Central to this effort has been the creation and maintenance of a central website where current information is posted, with status updates on research and how the public can help. The group also maintains a Facebook page to engage and update via social media.

It is now clear that the science and management tools in existence today cannot achieve the eradication of ROD from Hawai'i. Further, early projections of the potential loss of 'ōhi'a from infection and mortality rates in monitoring plots are sobering. To succeed in limiting the spread of ROD through the movement of infected materials, and to continue to engage the public in positive action in light of this information, greatly expanded efforts are required. In particular, efforts to educate key audiences about decontamination and the importance of not moving 'ōhi'a material needs to be expanded. One of the main organizational goals for the Outreach Team is to transition the *ad hoc* Team to add capacity and structure to better reach the many audiences statewide. This SRP proposes funding five full-time staff to aid in all ROD related education and outreach activities statewide. Such an investment into each island will greatly expand public engagement in the prevention of ROD spread.

A second goal is to activate and empower people to prevent the spread of ROD and protect remaining 'ōhi'a habitat. While the situation is serious, public outreach and engagement must focus on messages that highlight what can be done to help our forests. Similar campaigns have shown that the best way we can engage the necessary level of awareness and participation statewide, and move the public from emergency compliance to internalizing awareness and behavior change, is to engage a wide variety of community leaders on each island to help amplify the messages and diversify the message delivery mechanisms. People must take the issue to heart, become

Outreach and engagement has played a significant role in raising public awareness and support, limiting the spread of ROD even before the interim rule limiting movement of 'ōhi'a from Hawaii Island, and in the absence of on-island rules limiting movement of materials containing the pathogen. (ROD Outreach Team photo)

personally invested, and outreach must involve more leaders in the work of protecting and perpetuating healthy and resilient ʻōhiʻa forests.

The third goal is to ensure that outreach co-evolves with science. Knowledge about these newly-identified pathogens and their impacts is increasing every week, requiring a carefully coordinated statewide outreach program. Outreach should increase the percentage of the public who understand ROD and its impacts, and how they can help with prevention, mitigation, and eventually, with some form of forest restoration. Outreach must also be clear about the evolving nature of scientific research, provide timely updates to keep the public informed and communicate when new evidence requires a change in prevention methods. The objectives to reach these goals are as follows:

- New, full-time ROD outreach positions in each county
- Public awareness surveys and attitude assessments
- Outreach materials and media production and distribution
- Formation of new partnerships for wide-scale community engagement
- Development of curricula for schools and programs
- Hosting or participating in educational community events

Agency and private funds are being used to produce and install signage and cleaning stations at priority trailheads (Anya Tagawa photo)

The majority of the work and materials to-date have been via in-kind support from agencies and NGOs, while a portion has been supported through grants. The critical need to support this work in 2017 is $120,000 per island, which reflects a single FTE for outreach and engagement, materials, supplies, and a small number of trail signage and decontamination stations. The total need to accomplish all of the recommended actions statewide is $586,000 in 2017, and $540,000 each year in 2018 and 2019.

REQUIREMENT	
2017	$90,000
2018	$90,000
2019	$90,000

COORDINATION AND DEFINING ROLES

Tremendous progress has been made in identifying and understanding ROD, and in preventing its statewide spread. From the professionalism, dedication, and talent of the three original researchers, Drs. Lisa Keith, Flint Hughes, and J.B. Friday, this response now consists of more than 200 individuals from agencies, institutions, and non-government organizations (NGOs) in Hawai'i, the continental U.S., and internationally. Many of these individuals are contributing time, expertise, and resources to the ROD effort. The work to-date has been coordinated and communicated through the ROD Working Group, which is led by Dr. Ric Lopez of the USFS Institute of Pacific Islands Forestry. Monthly meetings/conference calls allow an opportunity for participants to provide or receive updates on research, management, and outreach. The purpose of the ROD Working Group is to facilitate inclusive ongoing discussions and communication of all issues related to ROD, and share knowledge on a regular basis among group members, their organizations, and has resulted in the formation of targeted teams addressing specific needs: the Early Detection and Rapid Response Team; the Outreach Team; the Science Team; the Operational Management Response Team; and the Strategic Response Plan Team, which has produced this document, in addition to the allied Maui ROD Working Group, and the Seed Saving Team. This SRP recommends continuing the subject-matter Teams approach and continued monthly meetings of the ROD Working Group as efficient approaches to disseminating new information and receiving important updates from the broad range of participants engaging the many facets of the ROD problem.

There has been outstanding cooperation and contribution of resources and staff from a wide variety of government agencies, non-profits, community groups, private foundations, and industry, and it has worked remarkably well thus-far. However, there is no clearly defined and transparent process for decision making, nor is there a formal decision-making body or structure for such a large and ongoing response. Organized and multi-pronged fundraising, grants management, resource and needs tracking, resource allocation decisions for critical needs, and reporting are all necessary functions that should be conducted in a more organized and transparent way. Therefore, the SRP also recommends that the ROD Working Group facilitate a transition from the current emergency response framework to a formalized strategic response framework, through the selection of a committee and decision-making structure which would serve these needs in a more sustainable and transparent manner. In addition to this coordinating team, which are proposed to be some of the individuals participating in the ROD response, this SRP recommends that a full-time staff position be created to administer the range of activities required to combat ROD, including the coordination of the transition from emergency response to strategic response.

This coordinating team and ROD response administrator would continue to work closely with the ROD Working Group, resource management and regulatory agencies, and the invasive species community including the Hawai'i Invasive Species Council, the Invasive Species Committees, Watershed Partnerships, and others. Resources to establish a coordinating body with one staff is $90,000 for each year, 2017, 2018, and 2019.

RAPID ʻŌHIʻA DEATH STRATEGIC RESPONSE BUDGET

Resource needs for Cultural Engagement

Item	Personel/item	2017	2018	2019	Total for 3 yrs
1	Hawaiian cultural specialist	$100,000	$100,000	$100,000	$300,000
2	Operational budget for workshops, travel	$20,000	$20,000	$20,000	$60,000
	Cultural Engagement Subtotal	**$120,000**	**$120,000**	**$120,000**	**$360,000**

Resource needs for Research

Item	Personel/item	2017	2018	2019	Total for 3 yrs
3	Forest pathologist post-doc	$100,000	$100,000	$100,000	$300,000
4	Molecular biology post-doc	$100,000	$100,000	$100,000	$300,000
5	Molecular biology technician	$60,000	$60,000	$60,000	$180,000
6	Pathology post-doc	$100,000	$100,000	$100,000	$300,000
7	Pathology technician	$60,000	$60,000	$60,000	$180,000
8	Pathology supplies & equipment (growth chambers, vehicles)	$241,000	$100,000	$100,000	$441,000
9	Entomology post-doc	$100,000	$100,000	$100,000	$300,000
10	Field technicians (2 FTEs)	$120,000	$120,000	$120,000	$360,000
11	Laboratory technicians (2 FTEs)	$120,000	$120,000	$120,000	$360,000
12	Field and lab supplies & equipment	$30,000	$30,000	$30,000	$90,000
13	Forest ecology technicians (2 FTEs)	$120,000	$120,000	$120,000	$360,000
14	Remote-sensing flights	$250,000	$250,000	$250,000	$750,000
15	Remote-sensing post-doc	$100,000	$100,000	$100,000	$300,000
16	Remote-sensing technicians (2 partial FTEs)	$75,000	$75,000	$75,000	$225,000
	Research Subtotal	**$1,576,000**	**$1,435,000**	**$1,435,000**	**$4,446,000**

Resource needs for Response to Threat

Item	Personnel/item	2017	2018	2019	Total for 3 yrs
17	Decontamination stations for vehicles/heavy equip.	$250,000	$50,000	$50,000	$350,000
18	Aerial and survey work (helicopter, plane, and ground)	$120,000	$120,000	$120,000	$360,000
19	Statewide survey crew (4 FTEs)	$255,000	$255,000	$255,000	$765,000
20	GIS/Data manager (1 FTE)	$100,000	$100,000	$100,000	$300,000
21	Survey equipment and supplies	$50,000	$50,000	$50,000	$150,000
22	Control ground crew (3 FTEs)	$190,000	$190,000	$190,000	$570,000
23	Equipment, supplies, contractor for operations, vehicle, etc.	$168,000	$100,000	$100,000	$368,000
24	Seed banking and restoration planner	$150,000	$150,000	$150,000	$450,000
	Response Subtotal	**$1,283,000**	**$1,015,000**	**$1,015,000**	**$3,313,000**

Resource needs for Outreach and Engagement

Item	Personnel/item	2017	2018	2019	Total for 3 yrs
25	Outreach/Education personnel (5 FTEs)	$450,000	$450,000	$450,000	$1,350,000
26	Outreach materials, signage, media, etc.	$136,000	$90,000	$90,000	$316,000
	Outreach Subtotal	**$586,000**	**$540,000**	**$540,000**	**$1,666,000**

Resource needs for Response Coordination

Item	Personnel/item	2017	2018	2019	Total for 3 yrs
27	Coordinating group staff (1 FTE, travel, operating costs etc.)	$90,000	$90,000	$90,000	$270,000
	Grand Total	**$3,655,000**	**$3,200,000**	**$3,200,000**	**$10,055,000**

RAPID ʻŌHIʻA DEATH
PART II: OPERATIONAL RESPONSE PLANS FOR 2017-2019

This Strategic Response Plan provides the framework for moving forward, but it does not provide details on operational logistics. These Operational Response Plans are being developed, with the Hawai'i Island ROD Incident Response Plan as an example. This Strategic Response Plan, a more comprehensive Guidance Document on Rapid ʻŌhia Death, and the Operational Response Plans will be posted at www.RapidOhiaDeath.org as they are developed.

ACKNOWLEDGMENTS

Mahalo to the following agencies, institutions, and organizations for supporting the ROD response through funding or contribution of staff time, resources, or in-kind support:

2016 Hawai'i State Legislature
Carnegie Airborne Institute
Coordinating Group on Alien Pest Species (project of UH PCSU)
County of Hawai'i
Department of Land and Natural Resources
Department of the Interior
Dorrance Family Foundation
Hau'oli Mau Loa Foundation
Hawai'i Conservation Alliance
Hawai'i Department of Agriculture
Hawai'i Invasive Species Council
Kanaka'ole family & Foundation
Koaniani Fund of the Hawai'i Community Foundation
Marisla Foundation
Merrie Monarch Festival
Gordon and Betty Moore Foundation
National Park Service-Hawai'i Volcanoes National Park
Office of Hawaiian Affairs
Representative Tulsi Gabbard & staff
Senator Brian Schatz & staff
Senator Mazie Hirono & staff
The Invasive Species Committees of Hawai'i (projects of UH PCSU)
The Nature Conservancy of Hawai'i
The Watershed Partnerships
U.S. Fish & Wildlife Service
U.S. Geological Survey
UH College of Tropical Agriculture and Human Resources
UH Lyon Arboretum
UH Pacific Cooperative Studies Unit
University of Hawai'i Foundation
USDA Agricultural Research Service
USDA Forest Service
And contributions of funding, expertise, or talent by many, many individuals—mahalo nui loa!