THE PINE PANDEMIC PREPAREDNESS PLAN
FOR THE SOUTHERN UNITED STATES

PINE PANDEMIC
PREPAREDNESS PLAN

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DEFINITIONS

Insect – an organism with six legs, an external skeleton with three body parts, and two antennae.

Disease – any condition in a plant caused by any living organism (a **pathogen,** including any fungus, bacterium, or virus) that interferes with the normal growth and development of any plant.

Forestry First Responder – a professional in the field of forestry who may routinely encounter pests and pathogens of trees before they have been diagnosed or treated.

Invasive species – any organism that causes ecological or economic harm to any plant in a new environment where it is not native.

Pathogen – any organism that causes a disease in another living organism.

Pest – any living organism, other than a vertebrate animal, in any stage of its existence, which is injurious or likely to be injurious to any plant.

ABSTRACT

Pine forests in the southern U.S. provide invaluable economic and ecological benefits to the region, the U.S, and many parts of the world. To protect and sustain these native pine forests, a diverse group of personnel and agencies co-developed the Pine Pandemic Preparedness Plan (P4) to be proactive plan with guidelines for forest professionals to be better prepared for a threat by a non-native and high-impact pest or pathogen on southern pines. The P4 contains the main steps necessary to curtail a new invasive threat rapidly, with minimal impacts to forests and the environment. This may also facilitate efficient use of diverse resources to effectively manage all pests and diseases in the long-term. We envision this document as a flexible guide based on the situation, and easy-to-use by anyone with a stake in sustainable forestry. The four central components of the P4 are: 1) Communication; 2) Detection and diagnosis; 3) Delimitation and assessment; and 4) Response. Each of these actionable and strategic components are consecutive and linked to each other to maximize communication, collaboration, and use of new and existing resources and entities to tackle a new invasive species, and serve as a complement to a state or federal emergency response. Implementation of this plan will involve teams integrating and generating information for dissemination to stakeholders and use in timely responses to protect southern pine resources from new pests and diseases.

INTRODUCTION

The vast, productive pine (*Pinus* spp.) forests prevalent in the 13 southeastern United States (U.S.) states provide tremendous economic and ecological values regionally, nationally, and beyond (Wear and Greis 2012, Moore et al. 2013, Boby et al. 2014). Loblolly (*P. taeda*), longleaf (*P. palustris*), shortleaf (*P. echinata*), and slash (*P. elliottii*) pines are the most extensively planted species monocultures in the region because of their fast growth and high productivity under intensive management. Also occurring in this region are eastern white (*P. strobus*), pitch (*P. rigida*), pond (*P. serotina*), sand (*P. clausa*), spruce (*P. glabra*), Table Mountain (*P. pungens*), and Virginia (*P. virginiana*) pines.

Southeastern pine plantations account for 61% and 57% of the total U.S. planted area and wood volume, respectively (Oswalt et al. 2014, FAO 2015), making the region the "wood-basket" of the world. Economic values provided by these pine plantations include pulp and paper, wood product harvest and manufacturing, and service industries associated with forestry. In total, forestry generates >$53 billion in revenue and >1 million jobs in the South annually (Southern Group of State Foresters 2014). Beyond plantations, southern pine ecosystems contribute to non-timber services that are equally important, including carbon sequestration, wildlife habitat, prevention of soil erosion, enhancement of water quality, recreational opportunities, and incredible biodiversity. Southern forests provide at least $30 billion worth of ecosystem services annually (Moore et al. 2013). Working and managed pine forests and pine-dominated forest ecosystems are national and global assets and need to be maintained and conserved for long-term forest sustainability.

However, southern pine forests face many abiotic and biotic threats (Gandhi et al. 2017). Abiotic threats include catastrophic wind disturbances, wildfires, drought, and flooding (Vogt et al. 2020). Biotic threats include native and introduced invasive insects (or pests), pathogens that cause diseases, and plants (Olatinwo et al. 2013). These threats vary across space and time, and interactions between threats worsen net impacts on pine forests. Global climatic changes are expected to alter many forest processes, impact abiotic and biotic factors, and threaten forest ecosystem resilience, leaving some plantations and forests especially vulnerable, with minimal resistance and resilience to pests and diseases (McNulty et al. 2013).

Non-native invasive species are introduced organisms (pathogens, pests, plants, or animals) that spread or expand their range from the site of original introduction and cause harm to the environment, economy, or human health. As a group, they are considered the greatest biotic threats to forested ecosystems, second only to agricultural and urbanization driven habitat loss (Moser et al. 2009, Mollot et al. 2017). The introduction, establishment, and spread of non-native plant consuming insects and plant infecting microbes continue to increase dramatically in the U.S. (Aukema et al. 2010). It is expected that more such incursions will occur (Myerson and Mooney 2007, Humair et al. 2015). Not all species new to the U.S. are invasive or damaging, but when damage does occur, the impacts can be severe such as when dominant canopy tree species are eliminated with a subsequent cascade of additional deleterious impacts (Gandhi and Herms 2010). Examples include emerald ash borer (*Agrilus planipennis*) on ash (*Fraxinus* spp.), chestnut blight (*Cryphonectria parasitica*) on American chestnut (*Castanea dentata*), laurel wilt (*Harringtonia lauricola*) on redbay (*Persea borbonia*) and sassafras (*Sassafras albidum*), and Dutch elm disease (*Ophiostoma novo-ulmi*) on elm (*Ulmus* spp.). In some instances, non-native pests and associated disease-causing pathogens were simultaneously introduced and impacted forest stands causing major cascading ecological effects (Loo 2008, Ploetz et al. 2017). As canopy trees become locally and regionally extinct, the impacts to local forestry dependent economies may be severe.

Only a few pine-damaging invasive pests or diseases are currently present in the U.S. For example, in the northeastern U.S., white pine blister rust (*Cronartium ribicola*) affects eastern white pines and red pine scale (*Matsucoccus matsumurae*) impacts red pines (*P. resinosa*). The Eurasian woodwasp (*Sirex noctilio*) has some impact on northeastern pines, but heavy competition for stressed trees from native bark beetles, woodborers, and woodwasps may be excluding these invasive wasps (that are capable of widespread destruction of pines in Australia, South Africa, and South America) from southern pines. In the South, through tools like thinning, cutting and removing infested trees, most managers are able to manage for healthy forests. Work on pine genetics (e.g., in resistance to fusiform rust, *Cronartium quercuum f.sp. fusiforme*) has also lent the resource advantage in the battle against native pests and diseases. Even outside the U.S., southern pine species are grown extensively with minimal pest problems (but see the Eurasian woodwasp). However, many pests and diseases that affect pines occur globally and could have severe consequences if they were to invade the United States.

In many parts of the U.S., forests are being lost or altered due to non-native invasive pests and diseases (Roy et al. 2014). Because regulations targeting only organisms that are already causing damage may be ineffective, some have called for revisions to existing international protocols for preventing non-native species entry and proliferation. Given all this, plus the presence of many ports of entries (e.g., Port of Savannah, Hartsfield-Jackson Atlanta Airport, and many more), we have significant concerns that a new damaging pest or disease may be introduced and established in pines in the region. Such an invasion could spread rapidly and cause extensive damage, lead to dramatic economic impacts and extensive ecological damages.

There is currently no ready to use systematic, coordinated plan to recognize and control a new catastrophic biotic threat specific to pines in the South. Many excellent agencies, institutions and resources exist in the region, such as the USDA Forest Service (USDA-FS), USDA Animal and Plant Health Inspection Service (USDA-APHIS), state forestry agencies, universities, extension centers, industrial and investment organizations and more, to protect pines from native and invasive pests. However, most private forest companies do not have in-house capacity to deal with high impact invasions and even within designated agencies resources may be limiting. Well-reasoned plans have been made, and previous work has been done to predict, rank, and prioritize potential future invasive pest and disease threats to our forests (e.g., Ries et al. 2004, Moltzan 2011, Dix et al. 2013, Swiecki and Bernhardt 2013, Hughes et al. 2015). As most plans are developed only once a new threat is established, they are mostly reactive in nature (Appendix A).

GOALS OF THE PLAN

This document, the **Pine Pandemic Preparedness Plan** (hereafter, **P4**), provides main guidelines for activities that are needed to recognize and stop the outbreak of a pest or disease that could threaten significant injury to pines throughout the southern U.S. By definition, a "pine pandemic" would affect multiple states and stakeholders and would be most likely to follow the introduction of a new non-native species. This plan differs from other forest health plans because the need for the plan was co-conceived by representatives from diverse organizations. The plan was co-developed by an even larger group of stakeholders with a vested interest in protecting and conserving pine resources: private landowners, foresters, forest product and investment companies, universities, and state and federal agencies in the South and beyond. Lastly, the plan is co-owned by all participating organizations, and the outcomes will be co-actualized and shared.

This plan has multiple benefits. The preparation of the plan helped to highlight numerous resources that are already in place and more that might be needed to protect southern pines. The plan also articulates roles for diverse organizations to act more strategically within their current capacities to prevent a widespread outbreak by a new pest or disease. The plan provides a foundation for forest health specialists and scientists to communicate and collaborate with political, social, and economic scientists to address any emerging high impact non-native pest or disease efficiently and rapidly. This plan will also begin to equip forest health experts and land managers to deal with a new invasive species once it starts making an impact. This plan intentionally does not call for more resources, though the team that developed this plan acknowledged the complexity of trying to prevent a pine pandemic with existing – often limited or fragmented- resources. This plan could, however, be useful to decision makers seeking to better understand the resources needed for adequate biosecurity for a vital economic sector. While it is focused on the southern pine resource, we see P4 as potentially being exportable to other regions and modified as needed.

It is important to note that at this point, the P4 is a guideline on how best to deal with an invasive high-impact species on pines; It is not yet at the implementation stage. However, as a group, we have provided major recommendations to allow the stakeholders to eventually marshal the resources necessary for the P4 to become live and to be implemented across the region. Such a collaborative effort would allow us to be truly proactive and to stop the invasions before they become a threat to our southern pine resources.

APPROACHES TO THE PINE PANDEMIC PREPAREDNESS PLAN

As the conceivers and facilitators of the P4, we requested assistance from a Core Committee consisting of a group of five thought leaders and strategic experts from various agencies and backgrounds. The Core Committee then assembled a diverse Task Force of ~20 scientists (academic, federal, state, and private and industry), a representative from the Southern Group of State Foresters (SGSF), industrial and investment land managers, and staff from state forestry agencies, the USDA-FS, and USDA-APHIS. The Task Force members are experts in their respective fields of entomology, pathology, modeling, tree breeding and genetics, silviculture, economics, social science, political science, private sector, federal, and state forest management, and federal plant pest and disease detection and management. We started with a subset of personnel to allow intensive discussions to take place, but widely disseminated the plan for input from any stakeholder vested in maintaining forest ecosystems. Further details on the plan preparation are found in Appendix B.

THE PINE PANDEMIC PREPAREDNESS PLAN (P4)

The plan is divided into four major sections: 1) communication; 2) detection and diagnosis; 3) delimitation and assessment; and 4) response. These sections are not mutually exclusive. The communication network underlies the entire plan and responses to threats are dependent on the diagnosis of a pest or disease and delimitation of its impact. We have highlighted the main points in each section, especially those which are actionable, below.

I. COMMUNICATION PLAN

A functioning stakeholder communications network will be a critical starting point. Inherent in this plan is the need to strengthen and more effectively utilize the existing communications network of forest health policymakers, scientists, practitioners, landowners, and the public. It is key to subsequent aspects of the P4. Approaches to a pine pandemic which are only developed after the fact will not allow an early enough response to minimize impacts.

Fortunately, networks exist that can serve as strong foundations for expanded efforts. Examples include the Pine Integrated Network: Education, Mitigation, and Adaptation Project (PINEMAP), the ProForest Southern Tree and Forest Health Diagnostics Group, the Southern Forest HealthWork Conference (SFHWC), SGSF, Southern Regional Extension Forestry (SREF), University Cooperative Extension groups, USDA-FS-FHP, USDA-FS-SRS, USDA-APHIS, university-industry tree improvement cooperatives, and others (Appendix C). These groups may include pathologists, entomologists, tree breeders, and other forest health workers. We have engaged with some of the specialists and researchers in these areas to receive input on lessons learned from dealing with past invasive species (Appendix D).

A change in the condition of southern pines must be reported immediately if it appears that a new pest or disease is involved, or if there is any uncertainty about the underlying cause. In the face of a novel pine health threat, messaging from the communications network will include sharing updates and reports, and coordinating alerts with forestry first responders (e.g., extension foresters, urban foresters, plantation foresters, arborists, etc.). This would be followed by communication with the SGSF at their annual meetings, and with Timber Investment Management Organizations (TIMO), Real Estate Investment Trusts (REIT), and other large landowners. Communication specialists (from the SGSF, the USDA, and state forestry agencies) would then work with press (online, print, TV, other media, science bloggers, and/or social media science influencers), non-government organizations (for advocacy, engagement, and management and research capacities), and policymakers (legislators, agency heads, mayors, and/or governors) focused on urgent issues needing a response. Communication needs to be both ways with information flow back to the practitioners.

A first order of business for P4 will be the creation of a **Communications Committee and Communications Plan** (**P4-COM**) for the initial rollout of the plan to the network. This could include a standard presentation for P4 team members to share in targeted presentations to key groups. These might also include forestry cooperative directors, federal and state forest health staff, state Departments of Agriculture, state forestry associations, USDA-FS-FHP and USDA-FS Eastern Forest Environmental Threat Assessment Center (USDA-FS-EFETAC), USDA-APHIS, and USDA-FS-SRS researchers. SFHWC could also host a standing P4 session each year with updates from a pine threat network or committee as part of a larger consideration of threats to all forest resources. The discovery of a new pest or disease impacting southern pines will put this network to the test in a fast-moving AND urgent manner. There will be the need for quick, consistent and efficient communication across multiple levels. The key is to discover the threat very early, and rapidly communicate its presence. Products exist that can assist with this early recognition. The USDA-FS-EFETAC's ForWarn (https://forwarn.forestthreats.org) is a data source to mine for potential threats. Another EFETAC product, Hi-form (https://hiform.org/) uses high resolution imagery, and before/after reference imagery that is only weeks old, allowing rapid detection of incipient infestations.

Continued communication is imperative. It will be critical that periodic reminders of the objectives of such an expanded network be shared. This may take the form of the following:

- Simple queries of network participants regarding any new/unexplained cause of damage or mortality in southern pines.
- Scenario response exercises and stress tests of the effectiveness of the network in communicating new threats.

A rapid response will be key to preventing uncontrolled spread, especially when communicating with forestry first responders. A simple, message like "if you see something, this is what you can do" would be followed by a succinct list of who to contact, and where to find more information. The more diverse the means of communicating these messages, the wider the audience that can be reached. Messaging may take the form of posters displayed in workplaces, email alerts, social media posts, short videos, and presentations to community groups and communications media. In most cases, there will be little prior information on possible threatening pests or diseases. If sentinel plantings outside the U.S. confirm some threats, background information (e.g., photos of the pest or the damage) can easily be included. Where there is uncertainty, it is essential to acknowledge it, identify what is known, and clearly describe how the problem is being investigated and managed. As covered in the subsequent sections, this is also the time to establish spatial applications for reporting and delineation of damage and pest or disease occurrence (e.g., EDDMapS by Bugwood; https://apps.bugwood.org/apps/eddmaps/). Early engagement with organizations for whom this is already their mission with little to no additional resources required is especially advisable at this early phase. This includes engaging with the USDA-FS-FHP and USDA-FS-EFETAC, and/or SREF to collaboratively maintain databases and websites. Working with economists (from academic institutions as well as the USDA-FS-SRS) can lead to the development of early predictions of economic impact. This information may be useful in raising awareness and mobilizing resources to address the emerging issue.

The goal in the early stages of discovery of a new pine threat will be to intervene and stop its spread. This goal becomes more difficult to achieve in subsequent time steps. The use of a P4 network will be essential to disseminate first reports in a short period of time, involving as many stakeholders as possible in the process. Several avenues of communication could be available for sharing the plan, communicating threats, and describing appropriate control and mitigation measures. For example, representatives from a P4 team could get time at a SGSF meeting to share the plan, seek input and answer questions. This could include utilization of effective pathways for communication among the public, landowners, and allied organizations: Forest Landowner Association, the National Alliance of Forest Owners, the American Forest

Foundation, the Association of Consulting Foresters, state wildlife agencies, non-governmental organizations (e.g., The Nature Conservancy, Conservation Fund), state parks, state forestry organizations, university extension programs, consulting foresters, arborists, forest industry (including TIMOs and REIT's), forest scientists with USDA-FS Research and Development, universities, and private research institutes (e.g., the Jones Center at Ichauway, Tall Timbers) (see Appendix C for examples).

The creation of a region-wide system for evaluation of tree damage and mortality by the P4 (P4-NET) will be essential. It will be important to establish a timescale for mortality evaluations. Such evaluations would be most effective on a quarterly or semi-annual basis. It will also be crucial to establish the managers and operators of such a system, as well as the level of automation involved in the process. Integrating the right methodology and technology is critical to developing protocols that can be implemented systematically across the region. This effort will require buy-in at the state and private level. Federal coordination and support may be necessary (or at least very helpful) in developing regional level, automatic processing, or smart systems. Tree improvement cooperatives and their member organizations may have multiage plantations which facilitate the detection and assessment of change. Real-time sharing of information must be a mainstay of this approach. This product can provide polygons of planted pine stands with some level of negative change detected, suggesting elevated mortality. From this, state forestry agencies receive GPS referenced reports of mortality in pine stands. As other forest health professionals become aware of mortality events in pines, the P4-NET can provide polygons indicating where evaluation plots can be established.

The fundamental currency of this phase will be reports from the field, preferably via a standard form and with a defined geographic location. Established, active data sources include several from the USDA Forest Service as:

- Forest Health Monitoring Program: This program within Forest Health Protection involves extensive collaboration with state partners. It is the only national data set documenting pest and disease perturbations in a spatially explicit manner and in real time. This involves a combination of aerial survey, ground survey, and remote sensing (Potter and Conkling 2022).
  - https://www.fs.fed.us/foresthealth/applied-sciences/mapping-reporting/
  - https://www.fs.fed.us/foresthealth/protecting-forest/forest-health-monitoring/index.shtml
- Eastern Environmental Threat Assessment Program
  - ForWarnII: This U.S. forest change assessment viewer allows detection of forest disturbance events including defoliation, severe weather events, bark beetle outbreaks, and more.
  - Hi-form; Uses high resolution imagery, better for small areas, and can use before/after reference imagery that is only weeks old, even days. So rapid detection of incipient infestations is much more likely https://hiform.org/.
- SouthFACT: This cooperative effort on behalf of 15 southern states provides GIS referenced state level forest health reporting. The effort is supported by the USDA Forest Service Region 8 and developed by the UNC-Asheville's National Environmental Modeling and Analysis Center.

- Forest Inventory and Analysis (FIA) reports nationwide on status and trends in forest area and location; in the species, size, and health of trees; in total tree growth, mortality, and removals by harvest; in wood production and utilization rates by various products; and in forest land ownership.

Regardless, data mining and pattern analyses efforts can focus on searching for clusters (spatial and/or non-spatial) among the field reports in terms of key attributes (e.g., pine species, setting, and type of damage/symptoms) and to compare report location patterns to signal departures documented in the sources listed above. These steps can be done statistically, though it will be necessary to set a sensitivity threshold for any such analyses. It will be necessary to report any anomalies up the chain and, ultimately, for the P4-COM to decide whether to announce publicly via websites and alerts on social media.

Communication Recommendations in a Nutshell

- The goal will be to stop the invasion very early in the process.
- Functioning communications and stakeholder networks already in place are critical.
- Strengthen and use existing broad communications network of forest health policymakers, scientists, practitioners, landowners, and the general public.
- Communication and information flow will be imperative to early discovery of a pine threat and successful intervention.
- The P4 Communication Committee (P4-COM) will act as a central hub for data, processing, and common messaging regarding a threat.
- The P4 network (P4-NET), a region-wide system will be essential for real-time evaluation of tree mortality.

II. DETECTION AND DIAGNOSIS

Detection and accurate and timely identification of potential and actual threats will be keys to success. Detection is defined here as mortality/damage events in southern pines that depart from expectations and have an identifiable biotic causal component that differs somehow from native biotic causes. The baseline mortality of pines is shaped by biotic and abiotic agents, tree/stand age, competition among trees for resources, and human activities.

Here plan users can draw from existing resources (Appendix C). The USDA-APHIS maintains staff and programs for analyzing risk using the Objective Prioritization of Exotic Pests model. The Sentinel Gardens project is likewise in place. Managers and researchers can capitalize on known threats by implementing the latest, sensitive detection tools in a risk-based manner (i.e., prioritizing locations that are high risk such as ports-of-entry). Horizon scanning is being used to identify poorly known threats that would be helpful for the plan. Here too, a defined communication network will provide a foundation for a horizon scanning exercise geared toward southern pines. In some cases, the necessary expertise for this exercise may be a degree or two removed from the immediate network.

One complication of these approaches is that departures from a baseline must be evaluated differently depending on the spatial scale. For instance, across the southern pine region we might typically expect 1-2% baseline annual mortality, but within an individual stand, we might see much higher mortality (e.g., >10%) that still conforms to expectations given the age class structure of the stand, combined with the possibility that we may be seeing cumulative mortality over several years in a stand that isn't actively managed or observed regularly. **For this purpose, a real-time P4 database within the P4-NET will be very helpful in assessing and recording such mortality patterns from multiple sources.**

The goals for this phase would be to:
(1) detect outside-the-norm occurrences of impact (mortality) in pines.
(2) identify the cause(s) if possible.
(3) even if cause(s) cannot be identified definitively, distinguish meaningful occurrences, i.e., pine mortality that may signal a potentially pandemic-level concern.
(4) trigger the appropriate P4 network participants depending on the level of concern as follows:

- P4-COM 1 = "standard alertness", nothing unusual to report at this time, but stay alert as always.
- P4-COM 2 = "heightened alertness/ initial mobilization", instances reported that might suggest a pattern, but mortality is localized and mortality levels remain relatively low. Further information gathering and pattern analysis is necessary. Analysts will be working and field personnel will mobilize to visit individual sites.
- P4-COM 3 = "full mobilization", a potential threat has been detected or a pattern is determined to be significant. Everyone involved in monitoring and surveillance, early analysis, and delimitation will be mobilized. Diagnosticians may be mobilized. Network stakeholders will be notified about the potential threat/pattern. This may include the public and news outlets, which may enable further discovery and information gathering. Phase III of the P4 is activated.
- P4-COM 4 = "maximum response", a threat is confirmed to have potentially pandemic-level consequences, or the threat has been determined to require an immediate response despite uncertainties. Everyone in the network is mobilized to do their part. Phases III and IV are both active.

Often, a new detection of a pine 'disturbance' can be quickly assessed by a knowledgeable state partner or extension agent – this should be the first point of attack always, before a snowball effect of communication and uncertainty about a possible threat unfolds, only to end up as a false alarm. It will be advisable to be smart about when there is a need to 'elevate' the rapid, widespread communication. For that, it may be necessary to have a knowledgeable, quick-reaction force in place. State forestry agencies are best equipped to fill this role. This may also apply to Detection and Diagnosis as well.

It will be critical to utilize new and existing networks to survey for pests and diseases, and to report their impact, extent, hazard, and risk to the resource. The Forest Health Monitoring program (USDA-FS) currently describes and documents significant tree mortality and its causes. In this plan we largely deal with scenarios in which a pest or disease has been present for some time and is already impacting a significant area. For a rapidly spreading new pest or disease, this makes it difficult to stop the damage. Ideally, early contact with USDA-APHIS and state invasive species councils would make effective use of their activity, expertise, preparedness, and awareness of potential and actual threats. As part of this effort, members of the P4-COM and P4-NET group can attend meetings, providing information on the importance of pine forests (including ecosystem services and economics), and the goals of the P4 project, reemphasizing the importance of communication throughout the response.

In response to reports of pest and disease damage or mortality, special detection surveys may also be conducted. Closer to the ground, detection of potential pest or disease problems may occur first in planted pines where they first start or at least can be most efficiently identified. Proximity to points of entry may also be an important factor in investment in monitoring efforts. We may not neglect the opportunity to implement tools to detect known risks. There have been recent papers describing sensitive tools for detecting known threats, and port environments and import destinations seem like a logical place for implementation since they're high-risk and we can't implement these tools everywhere.

Only 13% of forest cover in the South is federally owned and managed. However, national forests (particularly in Alabama, Georgia, Louisiana, Mississippi, and Texas) are heavily stocked with industrial loblolly pines, making the National Forest System an essential partner in P4. With private landowners, many of them owning <40 acres, dominating the southern landscape, local foresters (including state forestry units), forestry extension, and outreach agents (state based as well as colleges of agriculture and forestry) are key partners as well. Non-majority landowners may be best reached through working with minority serving institutions (HBCU, HACU, etc.), African-American landowners' groups, experts in heirs property law, and women landowner groups, as well as the SGSF. Large forest companies that manage pine plantations are an important group keeping close watch on their forest lands, with many making 3-4 passes through their forests during their rotational lifespans, and using remote sensing and drones. Specialized industries may also play a role in detection of new pine pests and diseases. For example, the pine straw industry and turpentine producers may frequent their stands more than many landowners. Additional avenues for communicating invasive species information may include distribution of information with state hunting licenses, or publication of forest health articles in departments of natural resources or other hunting magazines. Efforts will need to be made to engage with contacts in industry as well.

A standard evaluation protocol can be developed including:

1. At the impacted area, locate a damaged or dead pine tree, establish an area plot around that tree, quantify the number of dead trees (pine and otherwise), assign cause(s) of pine tree death, and upload data to system/database. The size of this plot is to-be-determined but could include a minimum number of additional pine trees closest to the target tree. That might work better to cover pines growing in a variety of settings including plantations, mixed stands, residential landscapes - any of which could prove relevant. What's key is that the standard protocol must involve field visits. Ground-truth observations and samples would be critical in at least some instances. It's probably unrealistic to visit every suspicious occurrence, but the focus here could be on certain situations or circumstances. For example, if the mortality evaluation network detects a possible pattern occurring among loblolly pines growing in residential landscapes, that provides a starting point. Also important is the definition of the minimum detectable unit. While we may be unlikely to detect the first instance of a threat (i.e., the very first handful of trees affected), we may be better able to do so when we have a few instances.

Regardless, everything would be feeding into the algorithm for evaluation of tree mortality.
2. System summarizes data and sends reports to the network and assigns any unknown causes of elevated death to pathologists/entomologists for further review.
3. Results of the review will be reported up through the P4-NET. However, to avoid P4-NET overlapping extensively with other existing databases and becoming overly cumbersome, it might be prudent to avoid logging anything into the system until it at least reaches the level of COM-3.

Resources to consider in addressing diagnosis of a new damaging pest or disease include:

1. Early Detection Rapid Response resources: United States Geological Survey: https://usgs.libguides.com/edrrinvasive.
2. North American Forest Commission Exotic Forest Pest Information System: https://www.invasive.org/species/list.cfm?id=5.
3. CABI Invasive Species Compendium: https://www.cabi.org/ISC.
4. North Carolina State University/USDA-APHIS Objective Prioritization of Exotic Pests database: https://cipm.ncsu.edu/partner-with-us/regulatory/regulatory-pest-informatics/.
5. Global Invasive Species Database: http://www.iucngisd.org/gisd/.
6. National Plant Diagnostics Network: https://www.npdn.org/home. This is a premier diagnostics system with over 70 diagnostic labs in 50 states and 4 territories (Puerto Rico, U.S. Virgin Islands, Guam, and American Samoa). These labs serve a diverse clientele on a wide array of plant health issues. The networks quickly detect and identify plant pests and diseases and communicate diagnoses to state and federal regulatory agencies, stakeholders and clientele.
7. University partners with forest health, pathology, and entomology programs.

Detection and Diagnosis Recommendations in a Nutshell

- Detection of mortality/damage that departs from expectations and has an identifiably novel biotic agent.
- Assessment of deviations from baseline tree mortality using both top-down and bottom-up approaches.
- Use of existing networks and contacts.
- Strengthening of diagnostic networks. Creation of new diagnostic networks as needed.
- Creation of a standard evaluation protocol for detection and diagnosis.

III. DELIMITATION AND ASSESSMENT

Delimitation and Assessment of impacts will be required for further action. Once there is evidence that a known new pest or disease is established or causing significant impacts, personnel can help create a monitoring plan which will itself provide some degree of readiness. Activities implemented as components of the P4 may be visualized as a timeline of relationships. Diagnosis leads to delimitation, which feeds into decision support for control and management, from which come long-term solutions. Early detection and rapid response are the next-best alternatives to prevention for invasive species management. Should a pest or disease capable of causing widespread pine mortality be detected, eradication or containment will be likely response options.

Delimitation is the process of defining the spatial extent (e.g., presence of an identified pest or disease or an area with abnormal tree mortality) and temporal persistence of the phenomenon of interest. Assessment, in this context, refers to forecasting the spread and impact of a pest or disease (or the expansion and area of mortality), as well as the resulting impacts with and without active management. Two events are likely to trigger this phase of the plan: 1) a pest or disease has been detected, identified, and classified as the potential cause of a pine pandemic, but its distribution remains poorly defined; or, more commonly, 2) an area of tree damage or mortality has been spotted but causal agents are unknown. Identifying the rate and mode of expansion, environmental influences, tree species, organisms involved, site quality, and vulnerable ecosystems will be critical for the assessment. Reliable delimitation and assessment will inform selection of appropriate response options.

Delimitation of pest and disease occurrence and assessment of their potential and real impacts often involves significant uncertainties. Most of the uncertainty stems from lack of knowledge about a novel pest or disease and of the forest stands that they might affect. Potentially tricky and difficult situations may arise when attempting to untangle the pest or pathogen 'signature' (symptoms) from other common disturbance agents, such as bark beetles, needle diseases, etc. Especially from aircraft or remote sensing. Likely, only on the ground assessments will be able to sort out if multiple disturbance agents are at work – so delimitation tools may be limited if the problem extends over a large area. Other unknowns may arise from inherent variability in the system such as variation in reproductive or disease spread rates, the influence of fluctuations in weather, interactions with hosts or other species, and more. As such, decision-makers may often integrate this uncertainty with local knowledge, expert opinion, and research results to plan a course of action. Steps and resources to consider in addressing delimitation of an outbreak may include:

1. Making use of available tools, resources, and partners:
    a. Forest Health Protection, USDA Forest Service. Forest Health Technology and Applied Sciences Team: https://www.fs.fed.us/foresthealth/applied-sciences/mapping-reporting/index.shtml.
    b. Forest Health Monitoring (FHM) Program https://www.fs.fed.us/foresthealth/protecting-forest/forest-health-monitoring/index.shtml. A variety of mapping and detection products, using surveys to collect geospatial data on the health of treed areas affected by pests and disease and store the data in a National Insect and Disease Survey database.
    c. ForWarn II, USDA Forest Service, Eastern Forest Environmental Threat Assessment Center: https://forestthreats.org/research/tools/forwarn/ A tool that could support forest and natural resource managers in delimitation, it can rapidly detect, identify, and respond to unexpected changes in the nation's forests impacted by pests, diseases, wildfires, extreme weather, or other natural or human-caused events.
2. Developing a standardized approach to using these tools.
3. Determining the responsible parties for the effort. There will be a need ahead of time to identify:

   a. Who has statutory and response authority?
   b. What resources will be necessary resources for an effective response, and who has the capability to respond in this way?
   c. Who has a stake in the decisions and actions?
4. Including partners in efforts:
   a. Forest health specialists with diverse training in diagnosis.
   b. Consulting foresters as eyes in the field: https://www.acf-foresters.org/
   c. State forestry organizations (SGSF) – forest health specialists (SGSF Forest Health Committee), and University Extension and Forest Health Faculty.
5. Seeking multiple perspectives (entomologists working with pathologists, field investigators and lab specialists, diagnosticians, and foresters) to reach more accurate and timely diagnoses.
6. Considering:
   a. Assessing patterns at multiple spatial scales, and reports from landowners and managers and other citizens, as vetted and coordinated by extension professionals can assist here. For example - the University of Minnesota Extension Service has the Forest Pest First Detector program: https://extension.umn.edu/natural-resources-volunteers/forest-pest-first-detector.
   b. A standard set of data to be collected, for use in regional and even national level analyses. This may include recording stand characteristics in addition to pest and disease information.
   c. A decision tree for use in delimitations onsite:
      i. Is the pest or disease that is causing disease appear to be a known native species?
      ii. What is seen in initial versus follow-up visits? Are patterns of impacts, signs, and symptoms the same or different?
      iii. Are there any additional noteworthy issues?
      iv. Distribute information widely and look for other areas.
      v. Possible additional questions:
         1. Are you seeing signs of pests or diseases?
         2. What symptoms are you observing?
         3. Have you seen this elsewhere this field season? Where?
      vi. Document the following:
         1. Site conditions
         2. Symptoms
         3. Any site history details gleaned from landowner
         4. Photographic samples
         5. Physical samples (ideally and if possible)
         6. Any guesses regarding the potential cause

Delimitation and Assessment Recommendations in a Nutshell

- Two events trigger this phase:
  - 1) Pest identified, classified as causal, distribution poorly defined.
  - 2) Causal agent unknown, but area of tree mortality identified.
- Delimitation defines extent and persistence of pest and/or mortality.
- Assessment forecasts spread and impact of pest and/or mortality.
- Fraught with uncertainties; use existing resources; define responsible parties.
- Synthesize the knowns and unknowns on the biotic agent.
- Standardize data collection protocols.
- Establish a real-time database with processeddata available to stakeholders.

IV. RESPONSE

Once the threat has been identified, action will be needed to promptly implement appropriate treatments to minimize impacts. Coordination between Federal, State, Tribal and private landowners will be critical to success. Recent successful examples include the Asian long-horned beetle response in South Carolina that benefitted by learning from past efforts and exhibiting well-functioning extension and government-university communication. Without knowledge of the specific pest or pathogen causing harm, it is difficult to provide specific treatment recommendations. However, we can provide broad guidelines for a response plan.

Who takes the lead? Typically, State Departments of Agriculture are charged with the invasive species management responsibility, and take the lead on addressing threats to forest health. They would work closely with landowners (Federal, State, private, or Tribal), where the threat has been detected, and could also ensure that their efforts are coordinated with the landowner groups. These professionals might especially be working with the USDA-APHIS, the lead agency for prevention of the introduction and establishment of organisms in the U.S. States may have different levels of resources. The priorities and gaps identified in the P4 may be of assistance in optimizing these resources. The P4 could be the main hub for providing information and support structure for state forestry agencies and other stakeholders. It will be critical that all stakeholders, especially forest industry, nurseries, and forest landowners, are informed and able to provide input into all processes and are given updates at regular intervals. This can be achieved through real time updated information flow through P4-COM.

A new incursion can be a complex multi-stakeholder problem. The role that science plays in rapid analysis and synthesis is important but interacts with social, political, and technical factors as pest or disease arrival transitions to incursion, impacts, eradication, and recovery (Evans et al. 2020). Upon discovery of a new pest or disease, there will be the need to deal with initial multiple management questions that can also be informed by P4 resources. Scientists may be called upon to share incomplete knowledge and results early on and regularly. Initial questions may include:

- What will be the impact of the pest or disease on the resource if no action is taken?

- If the pest or disease is contained, what actions could be taken to increase the chance of eradication?
- Can the pest or disease be eradicated at the initial site(s) where it has been detected?
- What measures would indicate the pest or disease has been eradicated?
- What is the tipping point at which the pest or disease can no longer be contained?
- If the pest or disease is eradicated, how long will it take until there is another incursion?
- Can the pest or disease be managed if not eradicated and at what cost?
- How did the pest or disease get here?
- What do we know about the pest/disease in its native range and/or or other parts of the world where it has invaded?
- What tools have been successful for eradication or containment in other places?

Other related questions may arise as the incursion is managed:

- How far can the pest or pathogen disperse?
- How many plants are infected, and where are they?
- Where might the pest or disease spread to next?
- What other host plants could be infected or infested and where are they?
- Do different pine species or genotypes vary in their disease or pest susceptibility?
- Is there more than one pest or pathogen biotype?
- Will the pest or pathogen survive the winter or summer? If so, under what circumstances?
- Can the destruction be quickly stopped through using silviculture, chemical control, and/or integrated pest management?
- Can genetic resources, biological control, molecular, or other solutions be used effectively if the damage cannot be stopped in the short term?
- How soon can seedlings from resistance breeding programs be used in plantings to reestablish economic and ecosystem services benefits?
- How can the determination of significant damage be made? How many signs and symptoms of pests or disease must be found to cause concern and trigger action? Every circumstance differs, but anything novel, outside experience of a forest health professional is worthy of vigilance and further examination at the least.
- When is the new infestation a rare instance or a spreading pandemic?

It may be useful for managers to draw on lessons learned from other systems (*see* Appendix D) – e.g., pine decline, laurel wilt, and Eurasian woodwasp (an instance of widespread concern, followed by research and definition of scope). What aspects of these situations worked well? What lessons were learned from how they were handled and how they played out?

Based on the pest or pathogen, local managers may need to develop a plan of action, a process that unfolds in an organized manner. Appropriate treatments will have to be decided upon, and the resources necessary to carry out treatments identified. A P4 Response Committee (P4-RES) comprised may serve as a resource, helping to evaluate all options and inform decisions on best courses of action. Some situations will call for immediate short-term measures, such as sanitation and chemical control, to contain or eliminate the infestation or disease. If the disease or pest problem expands or is already well advanced, it may be necessary to move to longer term strategies involving resistance breeding, biological control, molecular or other methods. Most situations will require several fronts or lines of attack to control the pest or disease. The committee could incorporate lessons learned from previous responses to invasions (Appendix D) and aid in creating a decision tree for managers to determine which types of management would be most successful, and the stage at which they might apply.

If the threat review process determines that quarantines, movement controls, and eradication treatments are necessary, the lead entities may create a team consisting of representatives from state plant regulatory agencies, state plant industry agencies, state forestry agencies, universities with forest health expertise, USDA-FS, and USDA-APHIS. Based on the type of pest or disease, the team may make decisions on the size of quarantine areas and treatments. If it were determined that a small portion of the state could be quarantined, emergency regulations may be developed to outline quarantine areas and actions and establish a state quarantine. The establishment of a state quarantine would then allow the USDA-APHIS to implement a parallel quarantine of the same size as the state quarantine. Without the more localized state quarantine, USDA-APHIS would quarantine the entire state, and many more citizens, businesses, and industries could be impacted, perhaps unnecessarily.

Based on the life history and other aspects of the pest or disease-causing pathogen, the team may develop a list of articles to be regulated, including all parts of pine trees and any other articles deemed necessary. The team may also outline conditions governing the movement of regulated articles, how issuance of movement documents would occur, how inspection and disposal of regulated articles would occur, the boundaries of regulated areas, how to remove areas from regulation, the expected costs and benefits of regulation, and the projected impacts to the environment and public health without regulation.

In impacted areas with high quantities of dead trees, the fundamental question may be "What can be done with dead wood?" Any options, including sell, move, dispose, or recover, may have consequences for pest or disease spread. The USDA-APHIS will not take regulatory action on small tracts. This could be very difficult if merchantable wood is affected, as the general recommendation in new incursions is not to move wood unless is has been properly treated (https://www.dontmovefirewood.org/). The P4 communication team and appropriate agencies would work with landowners to make them aware of the potential impacts of the particular pest or pathogen. Here, relationship and trust building will be important, as will keeping landowners involved in the process. Since most of these issues may occur on private land, representation of landowners should be embedded high up in the communication structure (e.g., Society of American Foresters, Association of Consulting Foresters, Logger Associations, etc.). Unity of purpose across ownerships will be critical to quick action.

Building a pathway model for pine movement would provide useful information to the P4 RES team. Data on wood movement, including mill maps based on input volumes, are available from the USDA Forest Service FIA, the SGSF, the University of Georgia Center for Forest Business, and various forestry cooperatives. A subcommittee of the P4 group may further explore development of this spatial model (perhaps using transportation models). The goal here would be to create a pathway model as a connected spatial network from real-time and up-to-date data. Even a model using historical data would be useful if real-time data are not practical. While is it perhaps unrealistic to expect all wood movement data to be available especially from the smaller mills, this may be a good starting point. This model may require some data privacy agreements, to handle concerns over competing interests sharing data, and assurances that none of the information will be used punitively. For this, significant buy-in from the private sector would be crucial.

The strategy of "Contain and suppress" may not be able to eradicate a given pest or pathogen but it could keep it from moving while the research community has time to investigate solutions and strategies. Question such as: what tools are available? These may range from feller-bunchers to biological control agents. It would be advisable at this point to ask whether there are established management strategies from other areas infested by the organism? These could be sources of information and inspiration for novel strategies for new invasives without reinventing current techniques.

If eradication is determined to be impractical, other short term reactive strategies (e.g., chemical control and silvicultural measures) could be used against the pest or disease. The exact strategies to be used are to-be-determined as based on the species, however the P4 may play a critical role in these recommendations and standardizations across areas. New emergency technology development may be especially viable and necessary here.

Chemical control options may be limited, and not rapidly available, if they are not already approved and labelled for widespread use. Most chemicals effective for use on trees involve injections or soil drenches, methods which can be slow, costly, and labeled to protect single trees rather than for widespread use. Possible exceptions may include more targeted compounds or biologicals [e.g., *Bacillus thuringiensis* (Bt) and others]. If it is determined that chemical control is necessary, P4 may ensure that appropriate agencies are included in control planning. These agencies may include the U.S. Fish and Wildlife for endangered species consultation, State Wildlife or Natural Resource agencies, Environmental Protection Agency (EPA) and, if federal funds are used, then National Environmental Policy Act (NEPA) assessments may be needed. Use of silvicultural controls may require close work with landowners and forest managers to test experimental methods of pest or disease control.

The development of resistant populations of trees may be an especially effective, if longer term, tool to counter future impacts of a pest or disease. Southern pines have been the subject of widespread genetic field trials and the source of genomic tools useful in comparing damaged/dead to healthy trees. These efforts will require seed collection, developing scions from affected and unaffected trees, and testing the resistance and resilience of the resulting progeny. The P4 may assist with establishing a diverse seedbank for the affected pine species, as working with other agencies.

There are several avenues for information related to tree genotypes. Established tree improvement cooperatives are already studying genotypes around the world in common garden settings. Forest companies have routine field-testing operations and are observing trees to make selections for breeding. The goal here would be to create communication networks to allow easy data sharing with companies. If the companies decide to join P4 in an intentional way with more experiments using common gardens using different pine species and genotypes to understand potential genetic resistance, that will be an added value. Those trials will be above and beyond – extra investment and the cooperatives and companies may gain other value as well. Previously successful efforts with fusiform rust and other diseases (e.g., the USDA-FS- FHP Resistance

Screening Center) offer a template for the future for resistance breeding to new pests and pathogens.

Monitoring of treatments will be important to ensure that control objectives are being met and to inform any needed changes to future treatment options, mitigation measures, and restoration efforts. The State Team will identify who will be monitoring and how monitoring information will be shared. Cooperative restoration projects would be conducted by federal, state, tribal, and private land managers, and non-profit organizations attempting to restore areas affected by forest health threats. Long-term strategies and support for breeding for resistance, silviculture, and biocontrol can be a part of this effort.

The lack of necessary resources (financial and workforce) may be a significant barrier to landowner and manager participation in eradication and control efforts. Some sort of compensation, incentives, or cost sharing may be necessary for rapid communication of information and rapid management. Likewise, declines in support over the decades for tree nurseries, resistance breeding, orchards, and diverse seed sources have resulted in a likely shortage of seed/seedlings available to meet future afforestation or reforestation demands. If a severe condition befalls much of the resource in a short time frame, this could become an issue. Here, federal and/or state disaster funding would be useful to incentivize landowners, managers and agencies to collaborate on rapid elimination of the threat as well as restoration from it.

Response Recommendations in a Nutshell

- Coordination of Federal, State, Tribal, and private landowners is critical.
- Determine who takes the lead on the response ensuring communication flow across many entities.
- P4 Response Committee (P4-RES) - States work with P4 RES on best control and management protocols.
- Determine the best courses of action for eradication and control/management including what is already known.
- Quarantine and any treatment will require significant coordination across many entities and agencies.
- Create a pathway model for pine movement in the region.
- Monitoring of treatments will be necessary to assess progress and success.
- There are short-term actions, but if they fail, what actions are required to re-establish forests.

CONCLUSIONS

We provide guidelines and recommendations for rapid detection and management of a new invasive pest or pathogen species on pines. Preparing for and managing non-native high impact species on trees is complex, resource-heavy, and involves a huge commitment by many personnel and agencies. The economic and ecological impacts of non-native pest or disease are shared by the larger communities with some sectors more impacted than others. The P4 is built by personnel with a vested interest in the greater good of southern pine forest. This allows for a stronger momentum built into the system and with each entity bringing their strengths and resources to the plan.

We envision this document as an off-the-shelf plan which can be used to maximum extent and modified as needed in the case of invasion by a high impact pest or disease. A next step for P4 would involve implementation of the plan with formation and maintenance of teams and leadership through needed resources, infrastructure, and official involvement of vested personnel and agencies. This will require underlying each component (detection, delimitation and assessment, and response) of the P4 with a communication plan. A focus on long-term sustenance of plans will require steady and substantial support. That can only occur with a strong commitment and buy-in from all the stakeholders of southern pine forests. Hence, this document also serves as an invitation to have in-depth and continuing discussions how best to achieve effective implementation of the P4 in a collaborative and cohesive way to achieve the goals of long-term southern pine forest sustainability.

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FIGURE

Figure 1. Working model to indicate the overall proposed structure of the Pine Pandemic Preparedness Plan (P4).

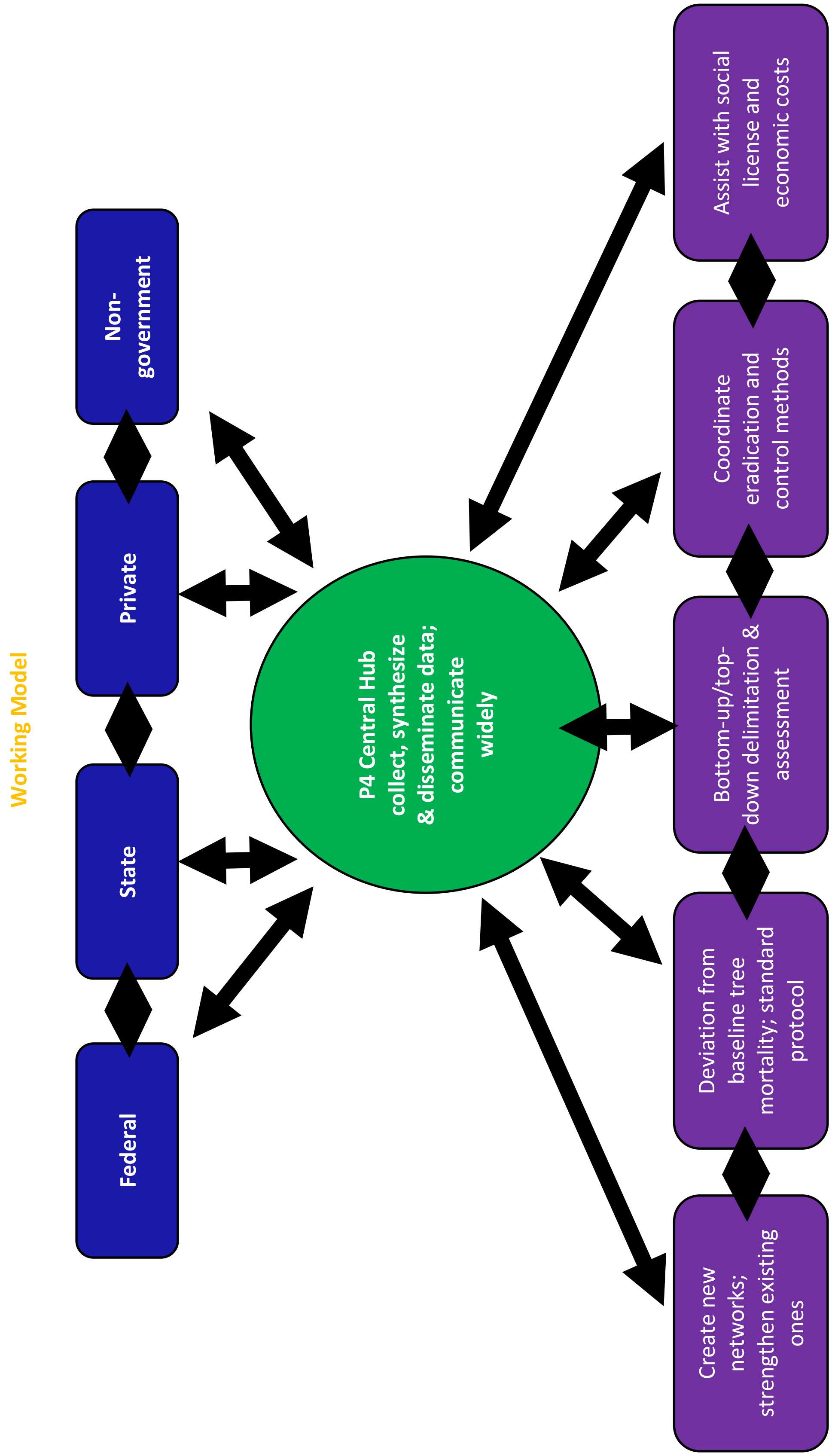
Working Model
Non-government
Private
State
Federal
P4 Central Hub collect, synthesize & disseminate data; communicate widely
Assist with social license and economic costs
Coordinate eradication and control methods
Bottom-up/top-down delimitation & assessment
Deviation from baseline tree mortality; standard protocol
Create new networks; strengthen existing ones

Figure 1

APPENDIX A: Plans and Resources Addressing Invasive Pests and Diseases

The **Emerald Ash Borer Management Strategy** seeks to minimize the impacts of EAB on urban and rural forests of the US. It identifies strategies and actions to guide how time, personnel and/or funds should be prioritized.

The **Rapid ʻŌhiʻa Death Strategic Response Plan** utilized a multidisciplinary strategic response plan team to develop and test science-driven management options, and formed multi-agency working groups for information exchange, effective resource allocation, and swift response to new positive detections. They have used an outreach team to engage the public using direct outreach, film, radio, print, and electronic media.

The **National Plant Health Emergency Management Framework** was developed by the USDA Animal and Plant Health Inspection Service to maintain the ability of agencies to implement an effective emergency response to invasive plant pest introductions. It aims to identify resources necessary for pest management, emergency response, and coordination. Resources to support this plan include several that may be useful to you as you manage a new invasive: PestLens, Cooperative Agricultural Pest Survey, National Identification Service, National Plant Diagnostic Network, National Biosurveillance Integration System, and Biosurveillance Indications and Warning Analytic Community.

The **Threat Specific Readiness Manual for *Fusarium circinatum*, the Cause of Pitch Canker**, understands that biosecurity emergency responses are most efficient if they are based on detailed knowledge of the life history, biology, ecology and susceptibility of the risk organism. It collates this information so it is readily available to inform decision-making, and proposes a high-level response action plan that broadly identifies the tools, methods and resources for containment, control and/or eradication.

The **Recovery Plan for Scots Pine Blister Rust** is one of several disease-specific documents (including a plan for Laurel Wilt) produced as part of the National Plant Disease Recovery System which seeks to ensure the tools, infrastructure, communication networks, and capacity required to mitigate the impact of high consequence plant disease outbreaks are available.

The USDA Forest Service **Early Warning System for Forest Health Threats in the United States** addresses catastrophic threats such as pests, diseases, invasive species, fire, weather-related risks, and other episodic events. It can be used as an aid to: understand the elements involved in early detection and response to environmental threats, help identify and remedy weaknesses in current early detection and response strategies, strategic planning and resource allocation. It includes a detailed application of this framework to forest pest and disease threats.

ProForest is a southeastern US based multi-institutional cross-discipline group working to proactively protect forest ecosystems and their services. They provide diagnostic and decision support services and resources. Their work on sentinel trees planted in China is identifying pests and diseases of concern.

The Eastern Forest Environmental Threat Assessment Center is part of a network of early warning activities established by the Forest Service nationwide. They predict, detect, and assess environmental threats to public and private forests of the east, and deliver timely, user friendly knowledge to managers. Their tools include the remote sensing based ForWarn system (discussed further in the plan).

APPENDIX B: Approaches to the Plan

Overall Approach:

Through a series of meetings between the Core Committee and Task Force we discussed the existing resources available in the region and the need for new approaches. Broad topics addressed were:

1. Prevention: Prediction, management, and communication based on understanding of organismal behavior, physiology, pathology, life history.
2. Ecological preparedness: Management and communication based on understanding of behavior of populations in landscapes, effective large-scale controls.
3. Social, economic and sociopolitical preparedness: Communications, knowledge and tech transfer as influencing social license and acceptance, implementation, cooperation, community needs, underserved land managers and local support.

Scenario Planning Exercises:

We provided the group with two scenario planning exercises to begin constructing the plan. Our focus here was on "incursion" management - dealing with a new (at least to us) pest or disease, recently detected, established, and causing damage to southern pines. This approach challenged our assumptions, values, and mental models of how we might respond to the incursion of a new pest or disease. We started with two scenarios to aid us in crafting a resilient and durable strategy. If we looked creatively at these possible futures, we identified strategies, and actions that will be appropriate for whatever situation we face. Finally, we considered what the potential scenarios told us about what we can and must do. These conclusions may be about actions that we need to take to adapt to things we cannot influence, or about actions to influence things we can.

For each scenario, began by considering the following:

1. What would you do if resources were not a limiting factor?
2. What would you do if you knew there was no chance of failure?
3. What would the future look like if we continue doing things exactly as we are?
4. What is the most likely future if your plan is implemented?
5. What is the best-case scenario you can imagine if your plan is successful?

Building on these foundational questions, consider your assigned scenario.
How would you respond at each time step?
What would have to be done?
Who would be involved?
Where are the gaps in our ability to respond effectively?

Scenario 1:

Private, peri-urban land
Time step 0: 20 acres of dead loblolly pines are discovered in forested areas around a Georgia town. Pest damage is observed but the species is undetermined.
Time step 1: Pest damage is observed on 200 acres within the county of origin
Time step 2: Additional areas of damage are discovered in neighboring counties. The pest or disease spread pattern appears to be a clear advancing front of damage.
Subsequent time steps are similar in pattern.

Scenario 2:
Forested, rural industry owned land
Time step 0: 20 acre patches of dead loblolly pines are discovered in forest and plantation land in Alabama, Georgia, and Mississippi. Disease symptoms are observed but the identity of the causal pathogen is undetermined.
Time step 1: Additional patches of mortality are discovered in non-adjacent areas.
Time step 2: Additional areas of damage are discovered in similar fashion. The disease does not appear to be spreading in a clear, advancing front.
Subsequent time steps are similar in pattern.

We further asked the group the following questions below using two scenario exercises:

1. What current resources can we draw from for prediction, prevention, and detection of potential pine invasives? What are the:
    a. Scales of these databases and efforts?
    b. Appropriate modeling approaches for prediction of potential invasives?
    c. Current efforts to search for and test potential pine invasives?
    d. Collaborative networks we can utilize?
2. What are new approaches we can utilize to deal with a new pine pest or disease at the pre-border, border and post-border phases?
3. How can we maximize the efficiency of current and new tactics and techniques? To what degree do these approaches need to be modified or adapted? Where can cross boundary cooperation aid in our efforts?
4. What are the barriers to greatest success for these approaches? How can we overcome them?
5. Communication: How, and how often, do we (core group and task force) communicate?
6. Metrics: How do we know we are addressing our action items as defined and on time?
7. Follow through: What has not yet been accomplished? What steps did we not think of that now need to be addressed?
8. Adaptation: What adjustments need to be made as the plan develops?
9. Timeline and Deliverables:
    a. Ready to use plan for use by land managers: 6 months
    b. Made widely available: 8 months
    c. Publication: 8 months
    d. Multiple websites, no one host entity: 8 months
    e. Signed Memoranda of Understanding to cooperate as needed on execution of plan: 12 months
10. Implementation of a new plan. What will we need to be successful?

APPENDIX C: Each federal and state agency and their website information

Agency Type	Agency	Website
Federal	USDA Forest Service, Forest Health Protection	https://www.fs.usda.gov/main/r8/forest-grasslandhealth
	USDA Forest Service, Southern Research Station	https://www.fs.usda.gov/research/srs
	USDA Animal and Plant Health Inspection Service (APHIS) – Plant Protection and Quarantine (PPQ)	https://www.aphis.usda.gov/aphis/ourfocus/planthealth
State	Alabama Forestry Commission	https://www.forestry.alabama.gov
	Arkansas Department of Agriculture	https://www.agriculture.arkansas.gov/forestry/
	Arkansas Forestry Commission	https://www.agriculture.arkansas.gov
	Florida Forest Service	https://www.fdacs.gov/Divisions-Offices/Florida-Forest-Service
	Georgia Department of Forestry	https://gatrees.org
	Georgia Department of Agriculture	https://agr.georgia.gov
	Kentucky Division of Forestry	https://eec.ky.gov/Natural-Resources/Forestry/Pages/default.aspx
	Louisiana Department of Agriculture and Forestry	https://www.ldaf.state.la.us/forestry/
	North Carolina Forest Service	https://www.ncforestservice.gov
	Mississippi Forestry Commission	https://www.mfc.ms.gov
	Oklahoma Forestry Services	https://ag.ok.gov/divisions/forestry-services/
	South Carolina Forestry Commission	https://www.scfc.gov
	Tennessee Division of Forestry	https://www.tn.gov/agriculture/forests/landowners/services.html
	Texas A&M Forest Service	https://tfsweb.tamu.edu
	Virginia Department of Forestry	https://dof.virginia.gov

APPENDIX D: Past examples of pests and disease responses

a) Southern Pine Decline or Loblolly Pine Decline:
    i) Observant growers, foresters, consultants, etc. noticed something amiss with mature, plantation-grown loblolly pine in some locations and started reporting it to colleagues, extension agents, academia, state agencies, etc. Information flow was strong, and worked its way through the network to reach the attention of experts. Response was outreach, research, and analysis – including publication of peer-reviewed papers which served to clarify the nature and extent of the threat.

b) *Sirex noctilio* in the Northeast U.S. This pest was on forest health specialist' radar for many years given it's spread to the southern hemisphere from its native Europe decades ago and notoriety as a plague on plantation grown, non-native pines such a Monterey pine in Australia and South Africa (Dodds and Groot 2012). Thus, there was some apprehension about it arriving in North America but little surprise when it was eventually found in New York state. Since, then, it has spread throughout parts of the Northeast, Midwest, and southern Canada. Advance knowledge, familiarity and experience with this pest facilitated rapid identification, communication, and evaluation among specialists. It was relatively quickly surmised that impacts to the pine resource in northeastern North America would probably be limited to stressed trees and not demand strong, costly intervention. Several reasons for this optimistic assessment were: 1) similar pine tree species as in its native Europe, where it's a minor pest; 2) a healthy complex of native parasitoid wasps were operating as natural enemies here, as in Europe (but unlike in the southern hemisphere); 3) an abundance of native wood-boring siricids that would serve as competitors for *S. noctilio* habitat niche, as in Europe, but also unlike in the southern hemisphere. Over time, these predictions seem to have been borne out, at least in the Northeast and the Midwest. It remains to be seen whether it will present a larger problem in the West or South, where the pine resource is particularly important and abundant. However, the same factors mentioned above (natural enemies, competitors, native pine hosts) are present in those regions, suggesting it will also be mainly a concern on overly stressed trees. In addition, pine management practices such as thinning are much more widespread across much of the South and have been highly impactful at limiting the impacts of the southern pine beetle over the last couple of decades. It is believed that these practices will also limit *S. noctilio*'s impact. Advanced knowledge of a pest that has already spread to other regions can be a huge planning tool. With such knowledge we are better attuned to what signs to look for and in a much better position to forecast how things might play out. From there, we can make contingency plans if it shows up here and be ready to implement them quickly or do nothing if the costs of taking an action outweigh the benefits. Dealing with known knowns like *Sirex* is more straightforward, the known unknowns (pests we know about but don't really know what they will do here) and especially the unknown unknowns (pests we don't know about at all – like emerald ash borer before 2002) are why the P4 is needed.