Southern California Shot Hole Borers/Fusarium Dieback Management Strategy for Natural and Urban Landscapes

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Table of Contents

PURPOSE 3

BACKGROUND 3

ACTIONS 5

1. Leadership and Oversight Coalition 5
2. Distribution and Density Surveys 6
3. Management Options - Short Term 7
4. Public Outreach 9
5. Research Leading to Long-Term Management 11
6. Timeline for Implementation 12
7. Seek and Direct Funding to Implementation Actions 12

Figures 14

Acknowledgements 17

References 17

Appendix A - Reproductive Host Lists 19

Appendix B - Natural Resources and Urban Forests Governance Structure 22

Appendix C - Orange County Parks Management Matrix 23

Appendix D - Bottle Trap Construction and Maintenance 26

Appendix E - Quarantine and Infected Material Handling Guidelines 31

Appendix F - Trapping and Monitoring Guidelines 34

PURPOSE

This document is a strategic approach for guiding and prioritizing actions and implementing control mechanisms necessary for the management of the invasive pests known as the Polyphagous Shot Hole Borer (PSHB) and Kuroshio Shot Hole Borer (KSHB), collectively referred to as Shot Hole Borers (SHB), and their fungal symbionts that lead to the plant disease *Fusarium* dieback (FD). This plan will provide land managers and stakeholders with implementation actions for natural resource communities and urban landscapes embedded into a regional framework designed to adapt to evolving Best Management Practices (BMP's). This management strategy will lead toward the effective control of the SHB/FD complex and prevent further damages to natural habitats and economic losses. Using the expertise of the lead researchers in the field the goal at this time is to prevent or reduce expansion of this threat into new areas and manage known occurrences of the beetle to eradicate invasive SHB from California. Further destruction is preventable if land managers, researchers, regulators, and funding agencies collaboratively work towards implementing common goals and avoid duplicate efforts.

Based on the already observed significant impact and apparent rapid expansion in southern California, it is imperative to provide clear management information to first responders at local, state and Federal levels regarding the potential for widespread impacts to agriculture, the nursery industry, urban landscaping, and riparian communities in southern California and beyond.

BACKGROUND

Invasive ambrosia beetles, discovered in southern California in stands of native and ornamental tree species, cause severe damage to riparian communities and urban areas[1]. This beetle is also a significant threat to the agricultural industry due to its use of avocado trees as a reproductive host, having already caused considerable economic losses (Eskalen 2016a, Kabashima 2016, Eskalen et al. 2013). Discovered in southern California in 2003 and misidentified as the Tea Shot Hole Borer (Eskalen et al. 2012). It was later determined that this was a unique species and given the common name, Polyphagous Shot Hole Borer (PSHB) (Eskalen et al. 2012, 2013). The species forms a symbiotic relationship with the *Fusarium* spp. fungus it carries within its mycangia[2] (Eskalen et al. 2013, Freeman et. al 2012, Mendel et al. 2012). PSHB carries two other known fungal symbionts, *Paracremonium pembeum*, and *Graphium euwallaceae* (Lynch et al. 2016). Mated female adult beetles initiate brood galleries by inoculating the walls of the gallery with the fungus as they bore into a host tree species (Eskalen et al. 2013). The fungi grow, and feed both the larvae and adults, eventually blocking the transport tissue of the host (Freeman et al. 2013, Mendel et al. 2012). This prevents movement of water and nutrients to the upper canopy causing associated branch dieback and tree mortality (Freeman et al. 2013, Eskalen et al. 2012, Mendel et al. 2012).

The plant disease *Fusarium* dieback, was not found in California until 2012, nine years after the initial discovery of the beetle vector (Eskalen et al. 2012). The beetle-disease complex has since spread throughout Los Angeles, Orange, Riverside, San Bernardino, and Ventura Counties and a separate invasion by the genetically distinct but morphologically indistinguishable Kuroshio Shot Hole Borer (KSHB) has occurred in San Diego, Orange, Santa Barbara, and San Luis Obispo Counties (Rios 2015, UCANR 2017). KSHB carries a *Fusarium* and a *Graphium* species; scientific description of both species is currently underway. Trap and lure data from throughout southern California indicate that the range of the species is rapidly expanding and preliminary research from the Paine lab at the University of California, Riverside (UCR) has determined that the SHB can survive as far north as Tehama County, possibly even into other parts of the country (Colin Umeda, UCR. pers. comm.). The beetle uses a wide range of tree species as reproductive hosts including both native and ornamental trees (Eskalen et al. 2013; Appendix A), facilitating its expansion and creating potential for dispersal throughout the state of California and beyond. Unlike most Scolytid beetles, both PSHB and KSHB prefer healthy, well-watered trees

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[1] **Current host lists can be seen in Appendix A**

[2] **Mycangia are special structures on the body of an animal used to transport symbiotic fungi (often as spores).**

(Boland 2016) (Swain et al. 2017). Attack symptoms exhibited by infected host trees vary by species and include staining, gumming, sugary exudates, and/or frass found outside of boring holes (Eskalen et al. 2013). These symptoms can be induced by other pest species (Dimson et al. 2015) and identification of PSHB/KSHB infected trees is difficult without proper training.

Controlling the spread of PSHB and KSHB is problematic due to the mating strategies of the beetles. Within a host tree, female beetles mate with sibling males prior to leaving the natal gallery and are capable of haplodiploid[3] reproduction (Cooperband et al. 2016), enabling both mated and unmated females to initiate new galleries within the same host tree (Eskalen 2015 personal observation) or colonize neighboring trees. These mating strategies cause trapping to be ineffective as a control method since no long-ranging pheromones exist to use as an attractant (Kabashima 2016). Trapping efforts are only effective for range determination and understanding beetle flight activity and are ineffective for management of infestations. Living host galleries protect SHB from contact pesticides, further limiting management options. The beetles' use of native, ornamental, and agricultural tree species as reproductive hosts complicates control of the pest and makes it necessary to manage all three types of landscape if adjacently located to one another. Failure to do so provides a source for eventual re-infestation of a treated site, negating any management effort. Lack of public awareness on the issue can lead to the artificial spread of the species. As with other forest pests that are prevalent in the region, the movement of firewood and unchipped beetle-infested trees and branches is one of the leading vectors for long-range transport of the disease to previously non-impacted areas (Buy 2015).

Current management options in agriculture and urban forests include the use of pesticides, chipping, solarization, and removal of infested material; management options in the natural setting are limited to chipping, solarization, and material removal (Eskalen 2016a, Lynch et al. 2016). The application of many pesticides and other topical treatment sprays is prohibited in or near aquatic habitats (CCR Section 6970) and their use is often impractical, making them a non-viable management option for these areas. Chip infested material to sizes smaller than one inch followed by the solarization or composting of chipped material (Jones and Paine 2015, Eskalen et al. 2014). Once composting and solarization processes are complete, the material can be repurposed and used as daily cover[4] at regional waste facilities, or for burning at biomass facilities (Wood 2016, Eskalen et al. 2014). Solarization times are dependent on the time of year and the cover material used (Jones and Paine 2015). This method is most effective during the summer months, but year-round use is possible if treatment times are increased (Jones and Paine 2015, Eskalen et al. 2014). Fully contain infested material during treatment to prevent beetles from escaping and establishing colonies in surrounding host trees.

Logistical issues arise when using chipping and solarization methods to manage areas with extensive damage. After the felling of infected host trees, managers are left with large amounts of woody material and biomass that must remain on site until the composting and solarization processes are complete or the material has been transported to a facility that has earned the U.S. Composting Council's Seal of Testing Assurance (STA) (Eskalen et al. 2014). Often the amount of space or equipment required for such an operation is unavailable, leaving infested material untreated. Trees that provide habitat structure necessary for nesting of some riparian species may become infested, and the stockpiling of woody debris may have negative impacts on the endangered arroyo toad, compelling management decisions to be site dependent and contingent upon the species present. Future long-term control options will likely involve some form of biocontrol from endophytic bacteria inoculations (Eskalen 2016b) and/or the introduction of a natural enemy, such as a parasitoid wasp, from its native range of Southeast Asia. These options will take years to develop and will require funding for further research prior to their implementation.

In southern California SHB has caused extensive destruction in riparian ecosystems. Within the Tijuana River Valley KSHB infested more than 280,000 trees, with more than 140,000 trees suffering major limb damage throughout 241 hectares (597acres) of primarily riparian forest (Boland 2016a, 2016b). This is unlikely to be an

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[3] **Unmated females produce haploid male offspring from unfertilized eggs, and mate with those offspring to produce diploid females.**

[4] **Layer of material placed on top of compacted landfill waste at the end of each day.**

isolated event and further damage of critical native habitat will occur if methods to control the beetle are not employed. Because of its wide host range (Eskalen et al. 2013), temperature tolerance (Eskalen 2016b), and lack of natural enemies, the SHB/Fungi complex could spread statewide and into other suitable parts of the country (Colin Umeda, UCR pers. comm.).

Organizations must implement a management plan aimed at limiting the expansion of the species, and prioritize investment for a long-term solution. Such an effort will require coordination across jurisdictional boundaries, industries, interest groups, and disciplines (i.e. entomology, plant pathology etc.) making it a considerable task to undertake. Such an effort is required if further losses of critical habitat are to be prevented.

Outlined below are actions for a management strategy. It is important to note that these actions will require continuous input from local managers and experts in the field over the course of multiple workshops and the management strategy be a living document adaptable to any new information or research that becomes available.

ACTIONS

1. Leadership and Oversight Coalition

Rationale: Establish a leadership coalition for coordinating funding, detection surveys, management, research, public outreach, and other objectives that may be incorporated into the management plan. Work with funding agencies to direct funding to address current management needs while working towards more effective management options, including large-scale efforts under the U.S. Department of Agriculture (USDA) and/or state agriculture agencies.

Implementation: A new coalition of Natural Resource and Urban Forestry interests is formed (Appendix B). The geographic scope of the coalition is infestation-wide. This coalition will coordinate closely with academic entities and with existing groups such as the Agricultural Commissioners Association, CA Forest Pest Council, and other statewide and national interests.

The coalition can form county-based subcommittees. These subcommittees can work with locally based interests and existing local groups, such as the Emerging Tree Pests groups. Incorporate stakeholders and constituents who work in areas with potential beetle infestations to effectively identify and manage new outbreaks.

Obstacles/Challenges: Creation of a new coalition will require time and effort. Funding to support the coalition is necessary, but could be provided by each of the agencies involved. Narrowing who is part of the leadership coalition and ensuring that the structure is adaptable to include neighboring county representatives should they elect to be part of this collaborative effort could prove difficult since there are numerous groups and organizations interested in the topic. Setting an agreed upon decision-making process and the method of distributing information to those without a representative would also need to be addressed. Consider creating a document to formalize the inter-governmental group organizational structure describing the functions of sub-committees and participatory agencies. An example of a similar document is San Diego's Principles of Understanding for the Intergovernmental Group on Feral Pigs. It allows for the clear delegation of responsibilities with a defined chain of command.

Measurable Objectives:

1. Formation of the governance coalition agreed to by key stakeholders. The entity that is created for this effort will have regular meetings and allow for input from the public
2. The leadership coalition should collaborate with agricultural, forest, and urban landscape agencies to leverage efforts and resources to establish larger scale efforts under the USDA and/or state agriculture agencies.
3. Distribute relevant information to stakeholders and the public in a multi-platform approach (website,

emails, documents, etc.). The Collaborative Tools communication and information sharing system hosted by the University of California Division of Agriculture and Natural Resources (UCANR) could be utilized for this purpose among land managers, researchers, and agencies. The public needs a different platform for communication. Refer to public outreach section for additional information.

4. It is crucial to establish a stated mission, objectives, and principles of understanding for the leadership coalition to avoid mission creep.
5. Oversee the acquisition and application of funds for distribution and density surveys, public outreach, short-term management and research for long-term management.
6. Coordinate between different agencies to achieve the objectives outlined in this document.
7. The coalition should form subcommittees as applicable.

2. Distribution and Density Surveys

Rationale: Based on the locations of known infestations, the wide range of suitable reproductive host trees, and the difficulties associated with field identification of infested trees, it is certain that KSHB/PSHB is present at locations throughout southern California that have yet to be identified. An initial step in effectively managing the species is to identify all occurrences within the region using a standardized survey protocol[5]. Simultaneously implement current management options, conducting public outreach efforts, and developing improved control strategies (actions three, four, and five of this document respectively). Surveys and monitoring will measure effectiveness of management practices, predict sites of SHB expansion and allow for comprehensive action.

Implementation: Develop an agreeable protocol and scaling system used to identify impacted areas and to categorize the severity of the infestation. Prioritize habitats for evaluation using criteria such as proximity to known infestations, presence of suitable reproductive host species, occurrences of rare or sensitive species within a site area, and if damage to the site area could have further implications, such as impacts to storm water control. Scoring from the scaling system will guide management action and prioritize sites for management effort. Surveys should also include information about surrounding habitat and potential for spreading SHB. Data of prevailing weather patterns, SHB emergence and host preferences will be crucial for predicting and preventing further expansion of SHB populations. Identify the potential for infestation and then determine whether to eradicate the infestation or control it from spreading. The Orange County Parks Management Matrix (Appendix C) serves as an example to follow, but full development of the protocol including a risk assessment model, will require further research.

The leadership coalition or subcommittee thereof will need to identify which personnel are qualified to perform the surveys; this may involve selecting a team of individuals to conduct assessments or training land managers to independently evaluate their lands using standardized methods. If necessary, UCR can process samples collected during surveys however additional funding and staffing would be required to handle the increased volume.

Obstacles/Challenges: Prior to selecting a protocol, decision makers need to determine to what degree of certainty beetle presence can be confirmed in the field by non-experts. If accurate identification proves to be too difficult, then experts may need to be included as part of the survey team. This may drastically increase the costs associated with region-wide surveys and may limit the extent of where they can be done. If land managers are able to accurately identify the beetle in the field, other obstacles such as lack of resources or staffing may become an issue. A team or organization will need to be identified to survey the urban landscape and any high priority private or publicly owned lands that are not part of Conserved Lands

[5] An overview of trapping and monitoring methods can be found in Appendix F

and do not have natural resource land managers. It is imperative that any field staff working in natural and urban landscapes be trained in identification in order to increase the probability of early detection when beetle levels may still be manageable (see objective three below and objective two of Public Outreach).

Sampling of infected host material for fungus identification may still be needed even if experts are part of the survey team. As mentioned previously, UCR can manage this task but it would require the allocation of funding for the increased volume in sample processing. Site access and permitting complications (e.g., right of entry permits, possible impacts to endangered species) need to be addressed for surveys to be completed in a timely matter. This may not be an issue if the land managers are performing surveys. Determining accurate population densities of SHB may be difficult because of the high number of variables, known and unknown, which can affect the beetles' reproduction in the field, and accessibility in areas with dense vegetation or other physical obstacles.

It will take time to develop relationships and a coordinated plan with agricultural and forest interests to leverage efforts and resources to establish larger scale efforts under the USDA and/or state agriculture agencies.

Measurable Objectives:

1. In cooperation with the key agencies and researchers, establish a standardized protocol for surveys. Trap design (for detection surveys), density, and processing will be included in the protocol. This would include a test to determine the level of training necessary to identify if there is an infestation and the method to confirm presence of PSHB/KSHB beetle.
2. Establish expert groups to assist with the identification of the infested areas. Members of this group would be available to land managers to call if there is a suspected infestation.
3. The University of California Cooperative Extension (UCCE) San Diego was awarded one-time funding from the County of San Diego for work to include workshops and field trainings for SHB identification for professionals (land management staff, arborists, etc.). If an agreeable protocol is developed, this training effort can be expanded to incorporate the methods and scaling system agreed upon and to educate interested parties on how to apply the management treatments. The San Diego Management and Monitoring Program (SDMMP) can assist in facilitating the training and coordinating interested parties.
4. Establish a central repository of surveys and results (both negative and positive) in a web based platform. Currently, positive results that are processed at UCR are included in an online PSHB/KSHB distribution map; the inclusion of negative survey results would require increased funding for in-depth assessment of all natural and urban landscapes. This information is required to implement any rapid response action. Include field data forms from the standardized surveys and archive for future comparison and for calculation of invasion rates.
5. Compare survey, emergence, and weather data to help predict possible infection sites for properly timed preventative treatments.
6. A GIS model should be created including known possible areas of infestation, existing vegetation mapping, water resources, and pathways for invasion (with urban trees and avocados orchards included), in order to develop a risk assessment model for the region. Shannon Lynch at the University of California, Santa Cruz (UCSC) is already working on this and the leadership coalition could promote her efforts. Recent work using aerial imagery has shown the potential to view areas currently experiencing dieback (Jason Giessow pers. com.).
7. Prioritize lands for management actions. The leadership coalition should decide the structure of that prioritization and appropriate management actions.

3. Management Options - Short Term

Rationale: Any long-term control strategy agreed upon will likely take multiple years to fully develop and implement. Land managers cannot afford to sit idle during this process if the beetle-fungi complex is present on their land. Rapid response options are required to impede the spread of the species from infested locations while a long-term solution is developed. Development of best management practices (BMP's) is need so that each land manager is using the best available practices.

Implementation: Short terms BMP's should focus on: a) reducing the spread of SHB, b) minimizing habitat damage, loss of ecosystem services, and loss of urban canopy, c) reducing the reproductive population of SHB. Management options will be dependent on the severity of the infestation assessed during the distribution surveys. Management strategies will be tiered, striving to achieve complete eradication of the pest species from a site if possible. If eradication is not possible, the management strategies will focus on preventing further spread of SHB and minimizing damage in affected areas. Using this model, assessment teams will determine which management level is applicable for a given site and each level will have specific management strategies associated with it (Appendices C and E). Prioritize management strategies based on feasibility, the amount of effort and funding required, and the impacts associated with the loss of habitat at a given site.

Management options will likely include a combination of solarization, wood chipping, prescribed burns (further discussion required), and removal of infected limbs (for composting). Although pesticides and fungicides have proven partially effective in urban and agricultural settings, these methods are not viable for natural wetland areas and are not a preferred method of control. No pesticides or fungicides have yet proven effective at complete eradication of SHB. The introduction of trees with specific endophytes may be useful in restoration following eradication of the pest and tree wrapping may help control the spread of the species, both of these options are underdeveloped and require further research. In some cases, replacement of heavily infected trees with non-host species can reduce reproductive potential. Deterrent chemicals such as Verbenone have shown success in reducing beetle attraction to traps with attractant lures and may be useful if used in conjunction with the aforementioned management strategies to reduce beetle movement into a previously treated site or non-infested area (R. Stouthamer personal communication). Currently the most effective method of control is chipping infected material to 2.5 cm or less, followed by solarization or composting.

In areas already damaged by SHB, take steps to encourage healthy and more resistant native plant communities. Downed woody material should be cleared away to promote recruitment of native seedlings. On average, 2.5 times more Arroyo Willow, Black Willow, and Mulefat seedlings were observed on cleared ground than ground covered with debris (Boland 2017). These willow species are affected by SHB but are only preferred hosts when their branch diameter grows above 4 cm (Boland 2017). The trees may remain alive in a shrub like state. The reduction of native canopy will provide an opening for invasive opportunists such as castor bean and *Arundo donax* to move in. Monitoring and eradication of invasive plants in SHB affected areas along with the planting of SHB resistant plants (Appendix A) will be key in reducing the further spread of SHB and invasive plants.

Urban landscapes can serve as refuge for beetle populations for later re-emergence. Education of urban landscape managers in best management practices will help prevent the spread or harboring of SHB. When selecting trees for urban landscapes, land managers should choose trees known as non-host, or non-reproductive host species (Appendix A).

Following management implementation, track effectiveness of management efforts and detect possible re-emergence of the beetle-disease complex in the area through trapping and monitoring programs. Incorporate monitoring programs into local restoration projects and mitigation banks, since these sites can provide researchers valuable information regarding beetle movement patterns into recovering areas. Traps constructed for minimal costs may be useful during initial detection surveys (Appendix D). Current monitoring programs used in the avocado industry involve bi-weekly inspection and replacement of funnel traps and on-site surveys conducted every three months. A similar program could be used as a starting point for the natural and urban landscapes and adjusted based on risk of habitat loss and the resources available.

Where possible, implement an urban observational monitoring program based on the model currently used in Orange and Ventura counties. Distribution of material on trap construction, handling of samples, and signs of beetle activity to communities can help identify and contain early outbreaks (Appendix D).

Obstacles/Challenges: Current available strategies for management of this pest species are inadequate for large scale infestations like the one observed in the Tijuana River Valley. This emphasizes the importance of identifying infested sites early before beetle densities are too high and effective management is no longer feasible. A given site may not allow for use of certain management strategies associated with the evaluated level of infestation. It will be important for management strategies to be flexible and adaptable to individual sites while remaining within the scope of the agreeable strategies and maintaining consistency in management across the region. Physical accessibility may be limited in certain areas and during certain times of the year due to terrain, vegetation or other physical barriers. Regulatory restrictions will affect accessibility of management options. Use of most pesticides is greatly limited in wildland areas, prohibiting some management options. Another regulatory restriction is the ability to access potential infestation on private property or property owned by agencies unaware of SHB. Depending on the proposed management action, lack of funding will be a key challenge. Short-term management will not be effective for SHB population control over longer periods. Short-term efforts should focus on reducing or preventing the spread of SHB while creating a long-term management strategy for population control.

Measurable Objectives:

1. Prioritize sites for management and monitoring activities based upon the distribution and density surveys. Prioritization of sites should consider feasibility, the amount of effort and funding required to achieve the goal for the site, and the impacts associated with the loss of habitat at a given site.
2. Prevention of SHB expansion is key to preventing further losses. Use BMP's to reduce the spread of the beetle/fungi complex. Public outreach and education will play an important role in preventing long-range spread of populations.
3. Short-term management options should be in alignment with the level of infestation and should follow agreed upon best management practices. Current options are limited for natural habitats and further research is needed to explore alternatives.
4. Monitoring of the site after management activities will allow land managers to evaluate the effectiveness of management actions and help ensure that no infestation/re-infestation occurs, eradication is achieved, or containment efforts are effective. Include monitoring data in any distribution map developed and used in the risk assessment model described above. (Distribution and Density Surveys Measurable Objective #4)

4. Public Outreach

Rationale: Education and incorporation of the public helps in the detection and reduction of SHB, and can prevent practices that spread pests to other areas of the state or country. The movement of firewood and unchipped beetle-infested trees and branches are a primary vector for spreading SHB and the associated *Fusarium* dieback. Publicly used facilities such as campgrounds and parks can be especially vulnerable to introductions of SHB since users may be unaware of the pest species and burning materials may have originated from impacted areas. Public outreach efforts such as those currently used by the County of San

Diego, UCCE, and UCANR are needed to limit firewood movement and prevent the long-range transport of the species throughout the state. Education of communities through the press, workshops, schools, volunteer organizations and other groups can lead to quicker discovery of beetle infestations, effective containment, and a reduction of SHB populations in urban and suburban environments. Programs should be implemented to include the public in monitoring, trapping, reporting, and containment, which would create a larger response network and increase public awareness.

Implementation: Work with County governments, the UC Cooperative Extension, and UCANR to expand existing outreach efforts. This may include increasing the number of people who receive this information, the number of channels used for dissemination, and the amount of material broadcast. Inform land managers and professionals that may be unaware of the issue and for communications regarding management practices and status updates through the Collaborative Tools sharing system currently used for internal communications by groups such as the San Diego Emerging Tree Pest Steering Committee (formerly the Golden Spotted Oak Borer Steering Committee) and the PSHB Working Group. Expand on UCCE San Diego's current outreach efforts to target these professional groups for trainings and workshops and these efforts. Prioritize professional groups most likely to come in to contact with infestations, such as arborists, orchards workers, land managers, nurseries, landscapers, and others who could influence the spread of SHB. UCCE has also been collaborating with the California Firewood Taskforce on public outreach activities including camper surveys and education, printed materials, billboards, etc. and increased funding would allow for production of increased fliers and the possible development of group specific materials.

Because of the increased influence of social media, employ an awareness campaign to disseminate knowledge of SHB. Use social media platforms to provide access to resources that will spread further through the networks of constituent groups. This would be an effective way to target a wider range of public groups and increase public awareness

Efforts should be made to disseminate information on trapping and monitoring into communities through schools, volunteer and non-government organizations, clubs, HOA's, and citizen scientist groups. The more people and groups participating in monitoring and eradication, the greater likelihood of stopping and reversing the spread of shot hole borers. Use social media, workshops, classes, school projects, and person to person outreach with organization leaders to incorporate communities and constituents in the management of SHB.

The PSHB Working Group will continue to manage the www.pshb.org website, which includes a mapping tool that indicates the current known locations of both, KSHB/FD and PSHB/FD (Figure 1), as well as handouts that provide people with information regarding acceptable handling practices and identification guidelines. The site is available for anyone to view and is promoted as a central source of information on the subject. Increased reliance on this site and additional visitor traffic and content maintenance, may require increased funding. Regional coordination and the identification of UCR as a sample processing facility by the leadership coalition may allow for quicker update of reported infestations in the mapping materials since currently they are unable to post infestations that they did not confirm.

Obstacles/Challenges: People receive their information through different avenues and outreach efforts should reflect this. Information on the SHB needs to be available through print, social media, radio and television broadcast etc. These efforts also need to be coordinated with neighboring counties to prevent duplicated efforts and to ensure information presented specifies that this is potentially a statewide issue. The public is saturated with new information and attention-demanding advertisements on a daily basis. Make material used for public outreach accessible and attention grabbing, examples of this are the graphic design of posters and flyers, or tailoring information for different groups to reflect their value systems.

Measurable Objectives:

1. Create and distribute informational flyers targeted to specific themes and audiences such as: outreach to reduce the spread of the *Fusarium* complex through firewood transport; increasing awareness of land managers and users of Conserved Lands to enhance detection; outreach to landscaping companies, tree trimmers, and arborists to recognize and report infestations; outreach to green waste companies to avoid transport of infested material to other areas. Distribute informational handouts to firewood distributers, rural businesses, camping equipment stores, campgrounds, day use areas, and to property owners in rural areas where dead trees are often cut down for free by firewood suppliers in exchange for the use of the wood (quantities to be determined by leadership coalition).
2. Engineer a social media campaign through major platforms (i.e. Facebook, Twitter, Instagram…) to spread awareness through constituent groups and the public. This network could be used for other future invasive pests.
3. Complete targeted training sessions for specific groups such as firewood distributers, land managers, landscapers and tree trimmers, green waste companies, and public utilities (quantities determined by leadership coalition).
4. Link local land managers and professionals to management, research, and status updates using an information sharing system such as Collaborative Tools.
5. Contact and provide information on monitoring, sample collection, and host symptoms to outdoor recreation and volunteer organizations, home owner associations, volunteer clean up organizations, schools, and citizen scientist groups.
6. Perform annual large-scale public outreach efforts with the goal of targeting every household in western San Diego County (done more frequently and to a larger extent as funding allows).
7. Install informational signage wherever firewood and/or landscaping waste may be moved and encourage "buy it where you burn it" practices.
8. Use and promote pshb.org as central source for information on PSHB/FD and KSHB/FD and coordinate reported infestations to allow for more rapid update of distribution map.
9. Conduct follow-up surveys after every outreach activity to gauge success of the outreach efforts, impact on the audience and any possible suggestions that could be incorporated in future activities.

5. Research Leading to Long-Term Management

Rationale: Current management options are extremely limited and are not conducive to controlling the spread of SHB or addressing heavily infested areas. Research in the field has been primarily funded by the avocado industry, meaning that the strategies examined may not be fully applicable to natural systems. There are multiple projects under discussion including the use of endophytic bacteria to limit the growth of the fungus and the introduction of a parasitoid wasp that attacks the beetle vector, a method currently being used in Hawaii for control of the coffee berry borer (Eskalen 2016a) (Figure 2, Figure 3). Discussion as to which options would provide land managers with the most applicable techniques and information needs to occur. Other research is proposed to examine the spreading mechanisms of the species and distribution patterns within a watershed. Funding efforts will need to be coordinated to guarantee a strategy for natural systems is developed and effective use of available money.

Implementation: Review current proposals and evaluate which projects may provide suitable long-term management strategies for control of SHB in natural landscapes. Completion of this task may need to take place before distribution surveys and outreach efforts since its implementation will require multiple years. Coordinate efforts among various agencies to direct funding towards the most promising research for land management. It is the responsibility of the leadership coalition to identify projects that prove to be the productive and coordinate funding opportunities to apply them in the field.

Obstacles/Challenges: Some of the proposed research topics may not provide managers a long-term solution for controlling the species and there may be differences in which practices can be used in the agricultural industry and which may be applicable to natural habitats. Interested parties will have to coordinate where funding should go and avoid duplicating efforts by other industries. A "silver bullet" solution is unlikely, and the application of multiple long-term solutions may be necessary to eradicate SHB.

Measurable Objectives:

1. The leadership coalition should review the funding options and align them with research proposals. Since the spread of the infestation can cross through native habitats, to urban areas and commercial agricultural groves (e.g. avocados), it is imperative to involve local jurisdictions, and statewide agricultural interests.
2. Explore a multi-pronged research effort. Include pilot projects to collect endophytes from native trees and evaluate their effectiveness at suppressing *Fusarium* species, upscaling endophytic bacteria suppressive to *Fusarium* species into existing native and nursery stock plants, testing the effectiveness of endophyte inoculation of mature trees in inhibiting infestations, exploring the effectiveness of SHB predators and entomopathogens that infect and kill the beetle, and determining the spread of invasion. Start pilot projects on all of these efforts, and coordinated to reduce the duplication of efforts.
3. Results of these pilot projects should feed back into the leadership coalition for evaluation and dissemination to land managers.
4. Work with partners to fund a competitive grant program that will draw research ideas from a broad scientific audience. Research from other pest/host systems (e.g., tea shot hole borer) may provide insight.

6. Timeline for Implementation

Rationale: SHB is rapidly expanding through wildland and urban landscapes. We need quick action to prevent widespread destruction of natural habitats and urban tree canopies. Creating a timeline of prioritized actions agreed upon by involved stakeholders will ensure completion of projects in a timely manner.

Implementation: Decision makers will need to determine priority of the tasks outlined in this document and to assign each with an expected time it will take to complete. Tasks and their timeframes may change depending on circumstances. Leadership and oversight committees will need to maintain forward progress and prevent mission creep.

Obstacles/Challenges: Many tasks outlined in this strategic plan will be adaptable and will change through time. This makes it difficult to assign an accurate timeframe. Region-wide plan development is often difficult to accomplish due to the large number of stakeholders involved. Different groups may believe in prioritization of different tasks, or may not have the resources available to accomplish a goal within the set timeframe. Leadership and oversight coalitions will need to make sure groups have the means to complete tasks on time, and maintain a clearly defined timeline.

Measurable Objectives:

1. Prioritize actions to effectively slow and reverse the spread of SHB.
2. Develop a timeline for these actions above to occur within six months.
3. Coordinate groups and resources to accomplish the set timeline.

7. Seek and Direct Funding to Implementation Actions

Rationale: The successful control of SHB requires multiple components dependent upon funding from a variety of potential sources. There is the risk of funding duplicate projects, and inefficient use of limited resources. Identifying all potential funding sources and which tasks to allocate available funding to, is critical for achieving the goals outlined and should be a key role of the leadership coalition.
Implementation: Propose a budget with estimated costs of individual tasks. These tasks may receive funding from different sources; a complete estimation of a budget will help to coordinate resources between agencies. Identify potential funding sources for individual tasks or for broader implementation. Take action to secure or access these funding sources and implement them effectively.

Obstacles/Challenges: The SHB and associated disease complex heavily affects both agriculture and habitat conservation efforts. Agreeing on the best uses of available funding may be difficult, especially when interested parties may have entirely different needs. Funds may come from multiple sources and granted for different purposes. This could lead to a lack of communication and cooperation between agencies and projects. Sharing of relevant information whenever possible between projects will use funds more effectively and allow quicker implementation of new management practices.

Measurable Objectives:

1. Estimate costs of tasks outlined in this document.
2. Develop a work plan and budget to complete the goals outlined in this document.
3. Identify funding sources
4. Take measures to secure funding needed to complete goals outlined in this document.

Figures

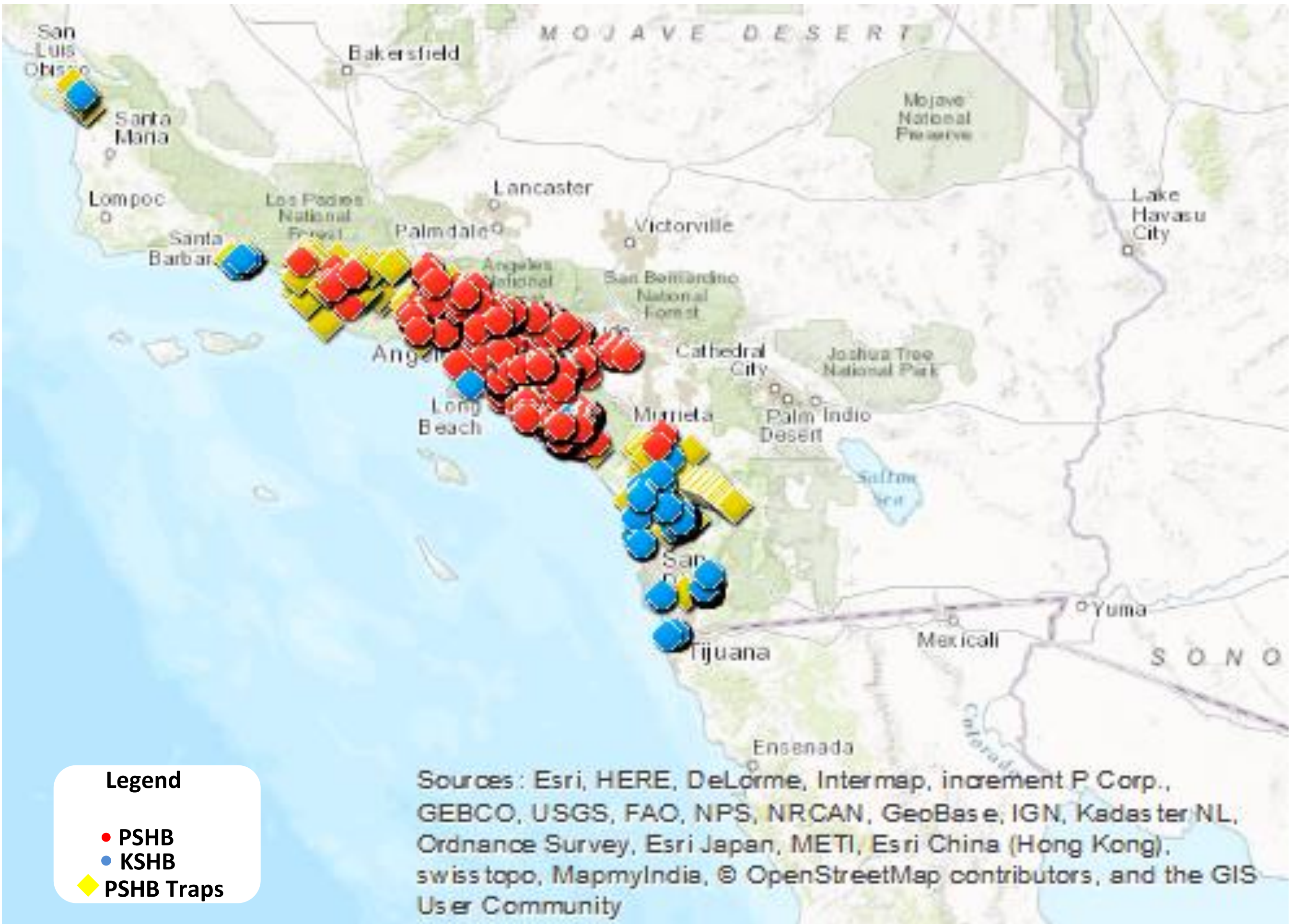
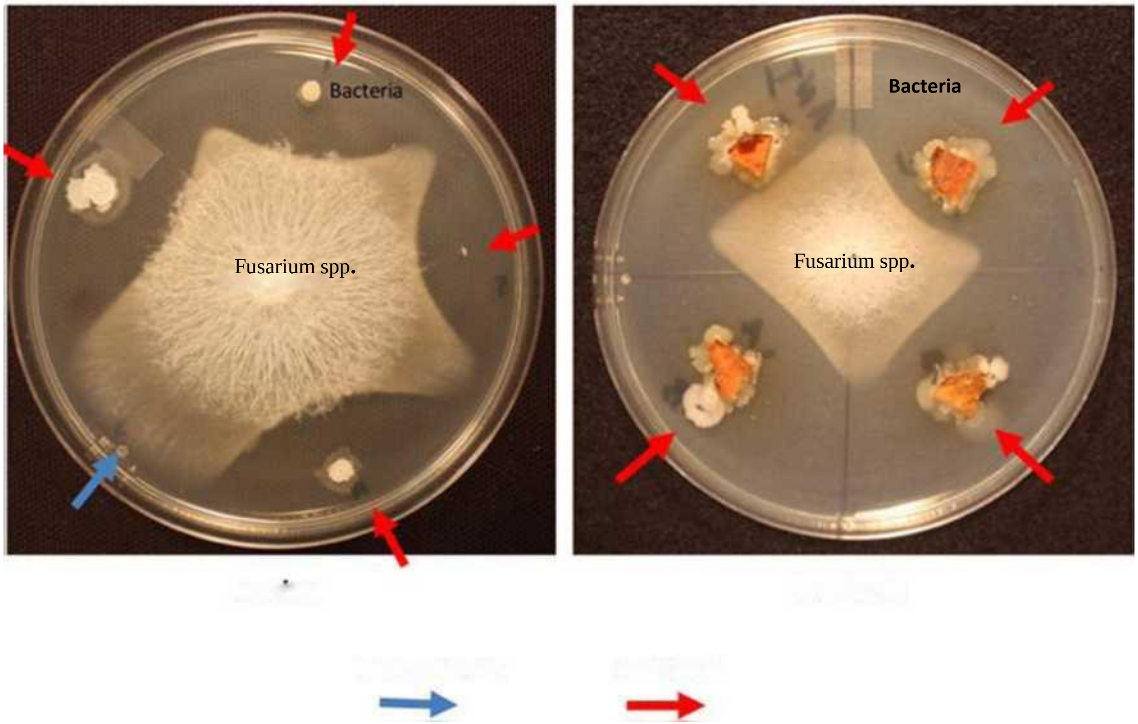


Figure 1: Known distribution in throughout southern California as of June 27, 2017. (http://ucanr.edu/sites/pshb/Map/).

Figure 2: Inhibition of Fusarium sp. by endophytic bacteria (Eskalen 2016)

In vitro **In planta**



No Inhibition **Inhibition**

Figure 3: Parasitoid wasp as potential long-term management strategy; also used for control of coffee berry borer in Hawaii (Eskalen 2016a).

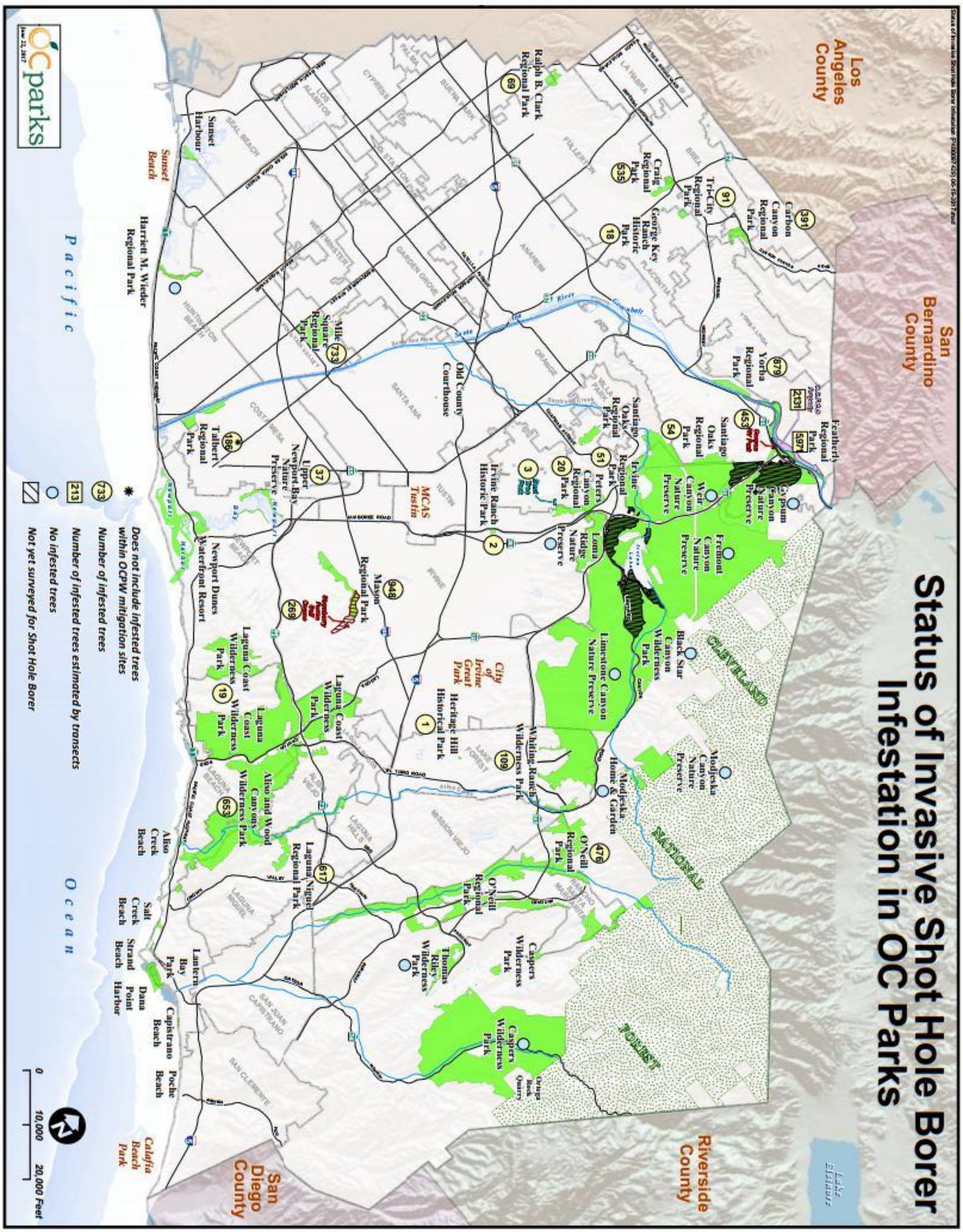


Figure 4: Extent of Shot Hole Borer infestation of Orange County Parks as of June 19th 2017

Acknowledgements

We'd like to thank the following organizations and individuals for their contribution to this document and all the time they've spent working on the topic: California Department of Fish and Wildlife, US Fish and Wildlife Service, San Diego Management and Monitoring Program, City of San Diego, County of San Diego, UC Cooperative Extension, Department of Agriculture, Weights and Measures, River Partners, UC Riverside, OC Parks, and researchers Dr. Akif Eskalen, Dr. John Kabashima, Dr. John Boland, and Dr. Richard Stouthamer. We would also like to thank Sheryl Landrum, Cathy Nowak, Bill Kirk, Rosi Dagit, David Zoutendyk, Gail Sevrens, Sarah Pierce, Melanie Tylke, Kevin Cullen, Kristine Preston, Janis Gonzales, Joey Mayorquin, and Joseph D. Carrillo.

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Appendix A - Reproductive Host Lists

Known Suitable Reproductive Hosts of Polyphagous Shot Hole Borer in California

1. Box elder (*Acer negundo*)*
2. Big leaf maple (*Acer macrophyllum*)*
3. Evergreen Maple (*Acer paxii*)
4. Trident maple (*Acer buergerianum*)
5. Japanese maple (*Acer palmatum*)
6. Castorbean (*Ricinus communis*)
7. California Sycamore (*Platanus racemosa*)*
8. Mexican sycamore (*Platanus mexicana*)
9. Red Willow (*Salix laevigata*)*
10. Arroyo Willow (*Salix lasiolepis*)
11. Avocado (*Persea americana*)
12. Mimosa (*Albizia julibrissin*)
13. English Oak (*Quercus robur*)
14. Coast live oak (*Quercus agrifolia*)*
15. London plane (*Platanus x acerifolia*)
16. Cottonwood (*Populus fremontii*)*
17. Black cottonwood (*Populus trichocarpa*)*
18. White Alder (*Alnus rhombifolia*)*
19. Titoki (*Alectryon excelsus*)
20. Engelmann Oak (*Quercus engelmannii*)*
21. Cork Oak (*Quercus suber*)
22. Valley oak (*Quercus lobata*)*
23. Coral tree (*Erythrina corallodendon*)
24. Blue palo verde (*Cercidium floridum*)*
25. Palo verde (*Parkinsonia aculeata*)
26. Moreton Bay Chestnut (*Castanospermum australe*)
27. Brea (*Cercidium sonorae*)
28. Mesquite (*Prosopis articulata*)*
29. Weeping willow (*Salix babylonica*)
30. Chinese holly (*Ilex cornuta*)
31. Camelia (*Camellia semiserrata*)
32. Acacia (*Acacia* spp.)
33. Liquidambar (*Liquidambar styraciflua*)
34. Red Flowering Gum (*Eucalyptus ficifolia*)
35. Japanese wisteria (*Wisteria floribunda*)
36. Goodding's black willow (*Salix gooddingii*)*
37. Tree of heaven (*Ailanthus altissima*)
38. Kurrajong (*Brachychiton populneus*)
39. Black mission fig (*Ficus carica*)
40. Japanese beech (*Fagus crenata*)
41. Dense logwood (*Xylosma congestum*)

42. Mule Fat (*Baccharis salicifolia*)*
43. Carrotwood (*Cupaniopsis anacardioies*)
44. California buckeye (*Aesculus californica*)
45. Canyon Live oak (*Quercus chrysolepis*)*
46. Black Poplar (*Populus nigra*)
47. Kentia Palm (*Howea forsteriana*)
48. King Palm (*Archontophoenix cunninghamiana*)
49. Tamarisk or salt-cedar (*Tamarix ramosissima*)

*Native species to California

Known Suitable Reproductive Hosts of Kuroshio Shot Hole Borer

1. Avocado (*Persea americana*)
2. California Sycamore (*Platanus racemosa*)*
3. Coast live oak (*Quercus agrifolia*)*
4. Cork oak (*Quercus suber*)
5. Draft coral tree (*Erythrina humeana*)
6. Black Polar (*Populus nigra*)
7. Black locust (*Robinia pseudoacacia*)
8. Red Willow (*Salix laevigata*)*
9. Arroyo willow (*Salix lasolepis*)*
10. Cottonwood (*Populus fremontii*)*
11. Mimosa (*Albizia julibrizin*)
12. Castorbean (*Ricinus communis*)
13. Black Willow (*Salix nigra*)*
14. Strawberry Snowball Tree (*Dombeya cacuminum*)
15. Mule Fat (*Baccharis salicifolia*)*
16. Tamarisk or salt-cedar (*Tamarix ramosissima*)
17. Coyote Bush (*Baccharis pilularis*)*

*Native tree species to California

Native Southern California Species Not Observed as Host Species or Not Severely Impacted by SHB

1. Manzanitas (*Arctostaphylos spp*.)
2. Saltbushes (*Atriplex spp*.)
3. Baccharises (*Baccharis spp*.)*
4. Lilacs (*Ceonothus spp*.)
5. San Diego Mountain Mahogany (*Cercocarpus betuloides*)
6. Desert Willow (*Chilopsis linearis*)
7. Spiny Aster (*Chlorocantha spinosa*)
8. Red Osier Dogwood (*Cornus sericea*)
9. Flannelbush (*Fremontodendron californica)*
10. Toyon (*Heteromeles arbutifolia*)
11. Coastal Goldenbush (*Isocoma vernonioides*)

12. California Boxthorn *(Lycium californicum)*
13. Bushmallow (*Malacothamnus fasciculatis*)
14. Laural Sumac (*Malosma laurina*)
15. Island Mallow (*Malva assurgentiflora*)
16. California Wax Myrtle *(Morella californica)*
17. Bladderpod (*Peritoma arborea*)
18. Pines (*Pinus spp*.)
19. Scrub Oak (*Quercus berberidifolia*)
20. Nuttals Scrub Oak (*Quercus dumosa*)
21. Interior Live Oak (*Quercus wislenzeni*)
22. Buckthorns (*Rhamnus spp*.)
23. Sumacs (*Rhus spp*.)
24. Fuschia Flowering Gooseberry (*Ribes speciosum*)
25. California Rose (*Rosa californica*)
26. Narrowleaf Willow *(Salix exigua*)*
27. Mexican Elderberry (*Sambucus mexicana*)*
28. Tule (*Scirpus spp*.)
29. Poison Oak (*Toxicodendron diversilobum*)

*Host species with less than 5% observed infection rate (based on data with n>7 per survey site) from:

Eskalen, A., Stouthamer, R., Lynch, S. C., Twizeyimana, M., Gonzalez, A., and Thibault, T. 2013. Host range of Fusarium dieback and its ambrosia beetle (Coleoptera: Scolytinae) vector in southern California. Plant Dis. 97:938-951.
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Orange County Parks, Aliso/Wood Canyons Wilderness Park Polyphagous Shot Hole Borer 2016 Survey
Orange County Parks, Mason Regional Park Polyphagous Shot Hole Borer 2016 Survey
Orange County Parks, Yorba Regional Park Polyphagous Shot Hole Borer 2016 Survey
Orange County Parks, Laguna Niguel Regional Park, Polyphagous Shot Hole Borer 2016 Survey
Orange County Parks, Featherly Regional Park Polyphagous Shot Hole Borer 2016 Survey
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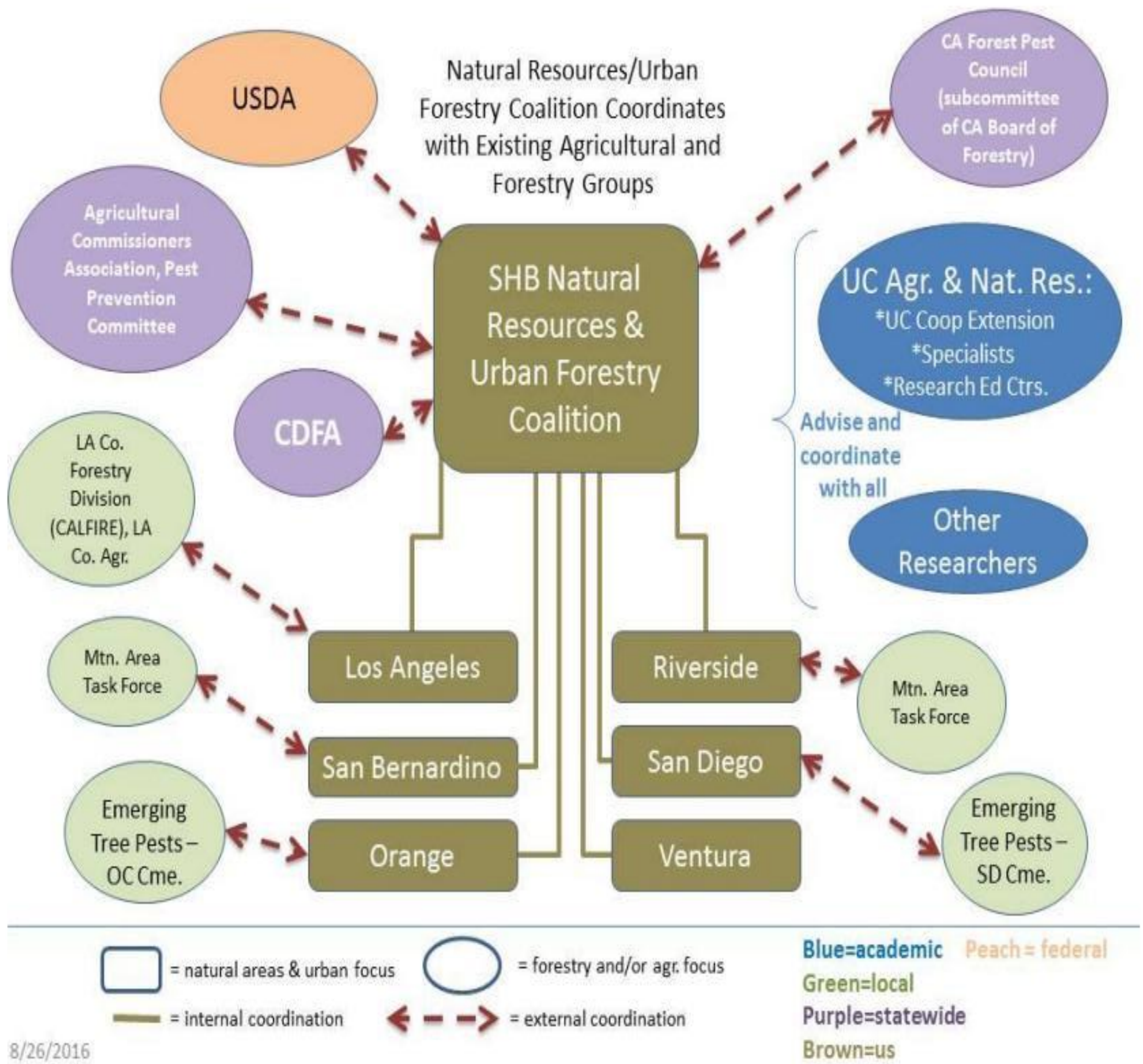
Appendix B- Natural Resources and Urban Forests Governance Structure



Appendix C - OC Parks Invasive Shot Hole Borer Management Guideline

The attached Guideline provides a decision matrix to guide management actions impacting trees in regional parks. It addresses such parameters as type of host, safety, value and level of infestation and how these criteria influence what management action is chosen---monitoring, corrective pruning, remedial treatment, preventative treatment or removal. Also provided is a prioritization hierarchy that focuses on preservation of high value trees and tree areas. This management Guideline will be adapted as new research/treatment options become available and is intended to provide an objective and consistent method for assessing trees that is science- based.

OC Parks Shot Hole Borer Management Guideline

Introduction:

This guideline is a tool for OC Parks staff engaged in Shot Hole Borer (SHB) management and will be updated as new research becomes available. It cannot anticipate every scenario that may be encountered in the field or replace professional judgement.

Researchers say SHB is established and will not be eradicated in Orange County, therefore OC Parks management strategy will focus on preservation of high value trees and areas.

Definitions:

Prioritization		
Area Criteria	Habitat, historic, iconic, amenity (e.g. campground), infestation level in surrounding area, potential for lasting benefit of management action.	
Tree Criteria	Native, large, historic, species, iconic, health, structure, infestation level.	
Treatment Prioritization	1. Large trees in un-infested facilities. 2. Large un-infested natives in infested facilities. 3. Large un-infested non-natives in infested facilities. 4. Large low to early Moderate I infested trees. 5. Smaller natives.	
Removal Prioritization	Removal will focus on protecting high value trees and areas. 1. Removal of Heavy and Moderate II infested trees in high value and high risk areas. 2. Removal of Heavy and Moderate II trees in low risk areas.	
Infestation Level	**Entry / Exit Holes**	**Dieback**
Low	Up to 50	No
Moderate I	50 to 150	No
Moderate II	150+	No
Heavy	150+	Yes
Value		
Low	Area or species of low economic, habitat, cultural value or smaller/younger trees.	
High	Area or species of high economic, habitat or cultural value (e.g. heritage trees), native, larger/older trees, trees that shade play equipment and campsites.	
Reproductive Species		
Yes	Species suitable for beetle reproduction and growth of Fusarium fungus.	
No	Species that have not yet proved suitable for beetle reproduction.	
Risk		
Low	Likely lower risk for people, habitat or property.	
High	Potentially higher risk for people, habitat or property (e.g. condition, proximity to trails, playgrounds, campgrounds, parking lots, structures).	

OC Parks Shot Hole Borer Management Guideline

Management Matrix:

Evaluation			Infestation Level & Management Options				
	Reproductive	**Risk**	**None**	**Low**	**Moderate I**	**Moderate II**	**Heavy**
Low Value	Yes	Low	Monitor	Monitor	Monitor	Remove	Remove
		High	Monitor, Prune, Rmv	Monitor, Prune, Rmv	Monitor, Prune, Rmv	Remove	Remove
	No	Low	Monitor	Monitor	Monitor	Remove	Remove
		High	Monitor, Prune, Rmv	Monitor, Prune, Rmv	Monitor, Prune, Rmv	Remove	Remove
	Reproductive	**Risk**	**None**	**Low**	**Moderate I**	**Moderate II**	**Heavy**
High Value	Yes	Low	Monitor, PT- I	Monitor, I, I/F	Monitor, I/F	Remove	Remove
		High	Mon, PT, Prune, Rmv	Mon, I, I/F, Prune, Rmv	Mon, I, I/F, Prune, Rmv	Remove	Remove
	No	Low	Monitor	Monitor, I	Monitor, I, I/F	Remove	Remove
		High	Monitor, Prune, Rmv	Mon, I, Prune, Rmv	Mon, I, Prune, Rmv	Remove	Remove
Treatment: PT = Preventative Treatment I = Insecticide F = Fungicide							

Treatment Options:

Reproductive Host (infested)	• Imidacloprid (I) drench, trunk or soil injection. • Propiconazole (F) trunk injection. • Optional - Pentra Bark+Cease (F) and/or Bifenthrin (I) trunk spray.
Reproductive Host (no infestation)	Preventative - may apply imidacloprid (I) drench, trunk or soil injection.
Non-Reproductive Host (infested)	• Optional - Imidacloprid (I) drench, trunk or soil injection. • Optional - Pentra Bark+Cease (F) and/or bifenthrin (I) trunk spray.
Non-Reproductive Host (no infestation)	High SHB populations, may apply preventative imidacloprid (I).
Buffer Treatment	Pentra Bark+Cease (F) and/or bifenthrin (I) trunk spray +/- 100' around heavy infested/removed trees or other special circumstances.
Tree Removal	Remove per tree management contract. Treat stump with bifenthrin (I) if not removed same day.
Agricultural Trees	Hero approved for use on Avocado (Expires April 8, 2017)
Irrigation must be shut off for 48 hours after soil drench or tree spray.	

Notes:

- As SHB work is prioritized (triaged) it is likely lower priority locations will be more severely impacted by SHB.
- Confirm trees are not part of UCR field study at Mason, Craig, Yorba or Carbon Canyon regional parks.
- All treatments require PCA review and approval.
- Trunk or soil injection preferred over tree spray or soil drench.
- Trunk spray generally effective no longer that three months.
- If SHB infestation is confined to the branches, the affected branches can be pruned if cuts are chemically treated.
- The best time to apply most treatments is between spring and fall.
- Follow tree maintenance contract procedures (located on Maintenance Support intranet page).
- Reproductive Host list: http://eskalenlab.ucr.edu.

Rev. January 2017

Appendix D- Bottle Trap Construction and Maintenance

From:	Porter, Eric
To:	Rice, Kvle: Greer, Keith
Cc:	David Zoutendvk: Patrick Gower
Subject:	Fwd: Trapping for shot hole borer in riparian areas
Date:	Friday, April 29, 2016 10:15:36 AM

Kyle,

There may be some useful information for you in this email. Dr. Stouthamer is probably the best contact for identifying/surveying for the beetles.

Eric

____Forwarded message__

From: **Richard Stouthamer** <richard.stouthamer@ucr.edu> Date: Fri, Apr 29, 2016 at 9:18 AM Subject: RE: Trapping for shot hole borer in riparian areas To: "Porter, Eric" <eric_porter@fws.gov> Cc: Patrick Gower <patrick_gower@fws.gov>. David Zoutendyk <david_zoutendyk@fws.gov>

Hi Eric

There are several trap types, the one that is the most efficient and most expensive is the 12 funnel funnel trap ($65), a intercept trap can be gotten for $28, the cheapest option is soda bottle traps that can be produced for maybe $1.50 these are the ones we intend to use in riparian areas where we may expect to lose many of the traps though vandalism or other human activity. There are two sources for the lures: the company synergy semiochemicals in Canada http://www.semiochemical.com/html/ambrosia_beetles.html in their website it says lure 3250 in reality this is now 3361. Last we checked the price per lure was about $12. The second company is chemtica http://www.chemtica.com/site/?p=5370 here the 60 day lure has the same longevity as the synergy lure. The price per lure here is in the range of $6.

If you use the bottle traps you will fill the lower bottle with soapy water and you will need to empty those bottles weekly otherwise the beetles caught in the trap will start to decompose. You can also fill the lower bottle with car antifreeze (important to use car antifreeze and not the environmentally safe RV antifreeze, the latter contains ethanol and then you will be catching lots of other ambrosia beetles which is a pain in the neck because you have to separate them from the PSHB and KSHB.) the beetles stay preserved in the car antifreeze for a longer period, so you could wait two weeks for servicing the traps. Of course some people consider the car antifreeze bad because it is relatively sweet and mammals may drink the stuff. This is generally not a problem with the bottle trap design.

We can train people in the identification of the SHB they all do look very similar but the lure generally attracts only the PSHB and KSHB as long as you do not add ethanol to the bottle. For the differentiation of kshb and pshb you will need to send the beetles to us, we use a dna based method to distinguish them

Your fourth question is difficult to answer we generally think that they do not attract beetles any further than 50m however that depends on so many factors that it is difficult to give a number. We generally make sure that they are at least 20 m apart from each other when we do tests with different lure compositions.

We are also putting in a grant to the years end FW funding with Kai Palenscar from the FW for the Santa Ana River to see if we can slow down the progress of the beetle.

Let me know if you have additional questions.

Richard

From: Porter, Eric [mailto:eric_porter@fws.gov]
Sent: Thursday, April 28, 2016 8:59 AM
To: Richard Stouthamer <richard.stouthamer@ucr.edu>
Cc: Patrick Gower <patrick gower@fws.gov>: David Zoutendyk <david zoutendvk@fws.gov> **Subject:** Trapping for shot hole borer in riparian areas

Hello Richard,

We are trying to organize more systematic surveys for shot hole borer infestations in riparian areas. Can you give me an idea of what all we need to consider in developing an approach. I'm looking for this kind of information to try write up a grant for funding. Here are some specific questions:

1) What is the cost of traps and lures?

2) How often do they need to be serviced?

3) What level of expertise is needed to identify borer (not necessarily to distinguish Kuroshio from polyphagous)?

4) What is the estimated area covered by a lured trap?

Thanks in advance,
Eric
Eric Porter

Carlsbad Fish and Wildlife Office

2177 Salk Avenue, Suite 250 Carlsbad, CA 92008

760-431-9440 ext. 285 Eric Porter Carlsbad Fish and Wildlife Office 2177 Salk Avenue, Suite 250 Carlsbad, CA 92008 760-431-9440 ext. 285

RESOURCE CONSERVATION DISTRICT OF THE SANTA MONICA MOUNTAINS

UC RIVERSIDE UNIVERSITY OF CALIFORNIA

Become a Detection Detective!

Help track the spread of Polyphagous/Kuroshio shot hole borers

Sign up to share your trap information and learn where to place your traps, how often to check them, how to collect samples, and where to take the samples you collect at www.rcdsmm.org/resources/oaktrees/trapping

TO BUILD YOUR TRAP

STEP 1.

Take 2L plastic soda bottle and measure 6cm from the bottom center along the side of the bottle. Mark it. From that mark, measure out and trace a 13 cm long by 17 cm wide panel on the outside of the bottle.

STEP 2.

Using the razor/box cutter, cut the panel out along the marked lines to create a large opening.

Materials needed:

Clear 2L bottle
**Pepsi products only*
Clear 16oz bottle
**Pepsi or Coke Product only*
Eye Bolts with Nut
5/32 x 1.5/8
Drill with 5/32 bit
3Dprinted
"Connector" OR
2" radiator clamp
Lure
Dawn dish soap
V-shaped coffee filter
Ziplock baggie
Sharpie

STEP 3.

Use a drill (bit 5/32") to create a hole at the bottom center of the bottle for the eye bolt and nut.

STEP 4. Insert eye bolt and secure nut to hole. Put 1 cup of water and 5 drops of Dawn dish soap into the 16 oz bottle. Twist on either a 3D printed connector (available upon request from the RCDSMM) or use a small 2 inch wide radiator screw clamp to connect the opening of the 2L bottle with the opening of the 16 oz bottle.

STEP 5. Attach the lure inside the 2L bottle by hanging from the nut end with a string.
Ambrosia Beetle Lure Product # 3361 cost $12@, last 6 weeks and should be ordered from Synergy Semiochemicals: http://www.semiochemical.com/html/ambrosia_beetles.html#lures

STEP 6. DEPLOY the TRAP: Traps should be placed on a stake or hung just outside of the dripline of the tree, approximately half way up the height of the trunk. . Take photo of the trap showing the tree as well. Fill in the information on the DETECTION DETECTIVE website to sign up and send in the photo and GPS coordinates.

STEP 7: Once a week, pour out the water from the 16 oz bottle through a V shaped coffee filter. Place filter in Ziploc bag, write date, name and address on it. Keep in the refrigerator until you drop it off at the RCDSMM office 540. S. Topanga Canyon Blvd., Topanga CA 90290. Please call ahead (818.587.8627 x102) to make sure someone is in the office to collect your sample!
Add more water and 5 drops of Dawn to the small bottle and reset the trap!

HOW TO MAKE A TRAP STAND

Most trees are not suitable for hanging traps. Pre-made trap stands are too heavy and cumbersome to ship economically. However, you can easily make reliable and durable trap stands that will last many years. This trap stand design has been tested and used successfully in the field.

1. From any hardware or building supply store (Home Depot or Lowe's), purchase a %", 8 foot length of galvanized electrical conduit (EMT).

2. With an EMT conduit bender, make a 90° angle bend at one end about 12 inches from the end. These benders cost around $40-$60 and are readily available.

3. Drill a 1/4" hole at about 1 inch from the end of the bent part.

4. To anchor the traps stands to the ground, use an 18-24" length of thin re bar pounded into the ground, leaving enough above ground so that you can slip the hollow trap stand over the re bar.

5. Think about the length of your stand compared to the size of the trap you will be using. Different insects require different traps and heights. Generally, for bark beetles and ambrosia beetles, the trap cup should hang approximately 18 inches from the ground, and you would shorten the conduit accordingly. Other traps such as Walnut twig beetle traps should be hung quite high so there is no need to cut the conduit.

6. Place a piece of wire through the drilled hole in the stand and attach to the trap canopy.

If you run into problems, give us a call. **Synergy Semiochemicals Corp.** Phone: 604-454-1122 Email: synergy@semiochemical.com Fax: 604-568-8502

Appendix E- Quarantine and Infected Material Handling Guidelines

Listed below is a synthesis of current management and treatment guidelines.

Quarantine Management Matrix for Trees Infected with Kuroshio and Polyphagous Shot Hole Borer

Isolated Infestation	Reproductive Host	Risk Value	Host Value	Infestation Level Branches Only	Infestation Level <50 entry/exit holes	Infestation Level 50-200 entry/exit holes	Infestation Level >200 entry/exit holes
Yes	Yes	High	High	Remove Limbs, Monitor Tree	Remove Tree, Monitor Area	Remove Tree, Monitor Area	Remove Tree, Monitor Area
			Low	Remove Limbs, Monitor Tree	Remove Tree, Monitor Area	Remove Tree, Monitor Area	Remove Tree, Monitor Area
		Low	High	Remove Limbs, Monitor Tree	Remove Tree, Monitor Area	Remove Tree, Monitor Area	Remove Tree, Monitor Area
			Low	Remove Limbs, Monitor Tree	Remove Tree, Monitor Area	Remove Tree, Monitor Area	Remove Tree, Monitor Area
	No	High	High	Remove Limbs, Monitor Tree	PT (I&F) Tree, Monitor Area	Remove Tree, Monitor Area	Remove Tree, Monitor Area
			Low	Remove Limbs, Monitor Tree	PT (I&F) Tree, Monitor Area	Remove Tree, Monitor Area	Remove Tree, Monitor Area
		Low	High	Remove Limbs, Monitor Tree	PT (I&F) Tree, Monitor Area	Remove Tree, Monitor Area	Remove Tree, Monitor Area
			Low	Remove Limbs, Monitor Tree	PT (I&F) Tree, Monitor Area	Remove Tree, Monitor Area	Remove Tree, Monitor Area
No	Yes	High	High	Remove Limbs, Monitor Tree	PT (I&F), Monitor Tree	Remove Tree, Monitor Area	Remove Tree, Monitor Area
			Low	Remove Limbs, Monitor Tree	PT (I&F), Monitor Tree	Remove Tree, Monitor Area	Remove Tree, Monitor Area
		Low	High	Remove Limbs, Monitor Tree	PT (I&F), Monitor Tree	PT (I&F), Monitor Tree	Remove Tree, Monitor Area
			Low	Monitor Tree	PT (I&F), Monitor Tree	PT (I&F), Monitor Tree	Remove Tree, Monitor Area
	No	High	High	Remove Limbs, Monitor Tree	PT (I&F), Monitor Tree	Remove Tree, Monitor Area	Remove Tree, Monitor Area
			Low	Remove Limbs, Monitor Tree	PT (I&F), Monitor Tree	Remove Tree, Monitor Area	Remove Tree, Monitor Area
		Low	High	Monitor Tree	Monitor Tree	PT (I&F), Monitor Tree	Remove Tree, Monitor Area
			Low	Monitor Tree	Monitor Tree	PT (I&F), Monitor Tree	Remove Tree, Monitor Area

Definitions

Isolated Infestation	**Yes** Adjacent trees do not show signs of infestation.	**No** Adjacent trees show signs of PSHB or KSHB.
Reproductive Host	**Yes** Tree species is listed as a known reproductive host,or a host of indeterminate reproductiveness.	**No** Tree species is listed as a known non-reproductive host.
Host Value	**Low** Trees of low habitat or economical value.	**High** Trees serving high habitat, cultural, or economic value .
Risk Level	**Yes** Trees that do not pose a threat to human health, safety or property if they were to fall or drop limbs.	**No** Trees that a risk to human health, safety, or property if they were to fall or drop limbs. (Trees in campsites, next to buildings, next to trails, etc.)

Shot Hole borers will often attack branch collars, causing structural damage. When monitoring trees, it is important to check for, and remove hazardous branches on infected trees. The red line on the photo to the right shows the branch collar area that SHB's prefer on several host species.

After confirming an infestation, determine the best course of action. Does the tree need limbs removed? Can pesticides or fungicides be applied effectively? Does the tree need to be removed? Select the management option based on the situation at hand that minimizes the spread of SHB, and damage to the surrounding ecosystem, while maximizing safety.

Use of pesticides and fungicides should be limited to prevent contamination of protected or sensitive areas. They will not be applicable in all situations. Before applications check that their use is prudent, safe, and legal. Trunk injections can lower tree health and increase risk of secondary exposure. No pesticides or fungicides have yet proven effective in SHB eradication, only in population reduction.[5,1]

"Preliminary results from ongoing pesticide experiments on sycamore trees suggest that a combination of emamectin benzoate (4%) and propiconazole (14.3%) applied as trunk injections in the wood (2-3" in the xylem), lead to a reduction in new beetle attacks over time on low-level infested trees. An earlier study also suggests that a combination of emamectin benzoate (4%) and tebuconazole (16%) applied as trunk injections in the wood were able to reduce new beetle attacks over time on infested trees. If the infestation level on a host is moderate to heavy, we also found some level of control with trunk sprays of bifenthrin (23.4%), and a soil drench application of the systemic insecticide imidacloprid (75%). It is important to note that the chance of saving a moderate to heavily infested tree is very low. **Note: These pesticides are only registered on landscape trees.** [The mention of these pesticides does not constitute a recommendation.]" (Eskalen et al. 2016)

Bacillus subtilis has proven effective in reducing recolonization on branch collars when used after removal of an infected branch when applied topically on pruning wounds.[3]
The semio-chemical Verbenone has shown to work as an anti-aggregation pheromone for shot hole borers, with tests showing Verbenone deterred beetles from traps baited with Querciverol.

Infected material should either be: a) chipped to less than one inch in diameter and solarized on site, b) Cut into sections and solarized or kiln dried. [4] Solarization under plastic sheeting should last a minimum of 6 weeks with temperatures underneath sheeting exceeding 55^{0}C.[4] Solarization may take 6 months or longer during winter.[4] Transport of infected material before solarization is complete should be restricted as much as possible to prevent possible transportation and further spread of SHB.[4] If material is being moved before solarization is complete, the material should be tightly covered or sealed to prevent further spread of SHB.[2] Tree stumps should removed on the same day as the tree if possible.[6] If the stump is not removed the same day, it can be covered for solarizaton, or treated with bifenthrin.[6] Tools used to fell, prune, or cut plants infected with SHB should be disinfected afterwards to prevent the accidental spread of fungal pathogens carried by SHB.[7,2] Pruning wounds or other injury to a tree left intact can be treated with a fungicide to prevent re-colonization by SHB.[6] After handling of infected material, perform a visual check on oneself and others to prevent possible beetle hitchhikers. Current uses of pesticides and fungicides have limited effect and have not proven effective at eradicating SHB from infected trees, only in reducing the rate of re-colonization in lightly infected trees.[1] When selecting trees for urban landscapes, or habitat restoration, land managers should choose trees known as non-host, or non-reproductive host species.

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2.Eskalen, Akif; Mayorquin Joey S.; Carrillo, Joseph D.; Lynch, Shannon C.; Kabashima, John; Paine, Timothy; Stouthamer, Richard; Byrne, Frank; and Joseph Morse. "Invasive Shot Hole Borers Threatening Trees in Southern California." University of California Integrated Pest Management Green Bulletin, Vol. 6 No. 3, Dec. 2016.

3.Eskalen, Akif; S. Lynch; R. Stouthamer; P. Rugman-Jones; T. Paine; J. Morse; F. Byrne; T. Coleman; J. Kabashima; M. Dimson; T. Thibault; D. Bery; S. Drill; F. McDonogh; J. Mayorquin; F. Na; K. Sugino; J. Carrillo; S. Feirer; "Current Studies on Polyphagous Shot Hole Borer/Fusarium Dieback". California Avocado Commission Presentation. 2015.
http://www.californiaavocadogrowers.com/sites/default/files/documents/Eskalen-PSHB-Grower-Presenation-Sept-2015.pdf

4.Jones, Michele Eatough, and Timothy D. Paine. "Effect of Chipping and Solarization on Emergence and Boring Activity of a Recently Introduced Ambrosia Beetle (Euwallacea sp., Coleoptera: Curculionidae: Scolytinae) in Southern California." Journal of economic entomology 108.4 (2015): 1852-1859.

5. Jones, Michele Eatough and Timothy D. Paine. "Potential pesticides for control of a recently introduced ambrosia beetle (Euwallacea sp.) in southern California." *Journal of Pest Science* (2017): 1-10.

6.Orange County Parks. "OC Parks Polyphagous Shot Hole Borer Management Matrix". Southern California Shot Hole Borers/Fusarium Dieback Management Strategy for Natural and Urban Landscapes Sept. 2016

7.Paine, Timothy; Jones, Michele Eatough; Eskalen, Akif; Dimson, Monica; and John Kabashima. "Invasive Shot-Hole Borers + Fusarium Dieback Prioritizing Management Efforts". Forest Health Protection, Region 5 Southern California. 2017.
http://eskalenlab.ucr.edu/handouts/prioritizingmanagementefforts4242017.pdf

Appendix F- Trapping and Monitoring Guidelines

An Overview of SHB Trapping and Monitoring Practices

Trapping

Because of their lack of aggregation and sex pheromones, and poor flying ability, trapping of SHB is ineffective for determining population sizes or reducing the total population. Traps can be effective at determining the presence of SHB, particularly for at risk areas that are not currently infected.
The most effective known lure as of June 2017 is Synergy Semiochemical Corp Lure #3361.

<u>Selecting a Trap</u>

- Lindgren Trap

A series of suspended, inverted cones draining into a collection cup, Lindgren traps are the most durable, and the most expensive. Insects fall into the trap and drown. Samples are preserved in a mixture of propylene glycol and water. These traps take longer to set up and service, but are the most effective at detecting the presence of SHB. Sample are preserved in the trap with propylene glycol, and removed by straining the liquid. Samples are then placed in alcohol for later DNA analysis.

- Elm Bark Beetle Traps

Non reusable, sticky paper squares, the Elm Bark beetle traps are effective for visual identification, but make DNA analysis of individual SHB species difficult. Elm bark beetle traps are cheaper and faster to service than Lindgren traps. Collect samples by removing the beetle from the sticky glue "stickum" and placing in alcohol.

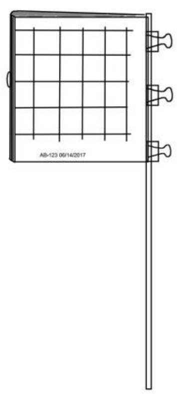

Diagram of an Elm Bark Beetle trap

8 Vane Lindgren Funnel Trap
Courtesy of Orange County Parks

- Liter Bottle Traps

Made from plastic 2 liter bottles, these traps are the least effective and the least expensive. They are serviced in the same fashion as the Lindgren traps. An example of the construction of the Liter Bottle Trap is detailed here
http://www.rcdsmm.org/wp-content/uploads/2016/11/Detection-Trap-DIY-Instructions.pdf

<u>Placing a Trap</u>

To improve detection of beetles, place traps along corridors of possible beetle movement.
DO place traps*;* in habitat with potential hosts, 3-5 feet above the ground, in open areas.

DO NOT place traps; in or under trees, in dense underbrush, in areas of high wind, near sprinklers or other irrigation systems, next to walls, near known infected trees, in heavily trafficked areas.
Trap Identification: Traps should be identified by using a unique alpha-numeric code. They should be marked with the date they were placed in the field. Whenever placing a trap, you should also record the state, county, agency, GPS coordinates, trap and lure type associated with that trap. You may want to consider recording the type of surrounding habitat, wind speed and direction, and air temperature. Be sure to use a pencil or pen with ink that will not run in alcohol or water.

- Lindgren and Liter Bottle Traps

Begin by selecting an appropriate site. Once a site is selected, hammer a 3-4 ft. length of rebar firmly into the ground, leaving roughly half the length above ground. A 4-5 ft. length of ¾" EMT conduit with a 90^0 bend is inserted over the rebar. The trap is then affixed to the top end of the conduit with wire or zip ties. The trap is then baited with a querciverol lure and the trap identification number is attached.

- Elm Bark Beetle Traps

After a site is selected, a stake is placed in the same manner as for the Lindgren and Liter Bottle traps. A straight 4-5 ft. length of ½" EMT conduit is placed over the stake. The trap is marked with its identification number and the lure is attached to the twist tie at the center of the trap. Two outer edges of the trap are clamped to the conduit with the "Stickum" facing outward, large binder clips may serve as clamps. Be sure the trap is firmly attached to the conduit and will not be blown away by the wind.

<u>Servicing a Trap</u>

When servicing traps, record the date serviced, if a sample was taken or if SHB are present, if and when the lure was replaced, if the trap was missing, replaced or damaged, and the weather. Do not place live beetles into plastic bags. Any live beetles taken for samples should be drowned in alcohol if they are going to be placed in a bag. Traps should be checked as often as possible to ensure detection, and should not be checked less frequently than once every two weeks.
Querciverol lures should be replaced every 6-8 weeks to ensure efficient release of semiochemicals, and should be stored in a freezer until they are used.

- Lindgren Traps

Materials required: sample containers, propylene glycol, water, 80% ethanol, sealable container for used propylene glycol/water, replacement lures, zip ties or wire, scissors or wire cutter, paint strainers, funnel, collection form, pen or pencil, sharpie or grease pencil
Personal Protective Equipment: chemical resistant gloves, dust mask, eye protection
When servicing Lindgren traps, begin by carefully removing the sample cup without spilling the liquid and strain the liquid through a conical paint filter and funnel into a sealable container. Remove any potential samples from the sample cup, rinsing the cup with water and pouring the water through the strainer if necessary. Preserve samples in 80% ethanol for DNA analysis. Be sure to record the trap number, location, and any other relevant information on the sample. Place a fresh solution of 50% water and 50% propylene glycol in the sample cup and the cup is placed back on the trap. If the lure has not been replaced for 6-8 weeks, it should be replaced.

- Elm Bark Beetle Trap

Materials required: sample containers, 80% ethanol, replacement lures, replacement traps, replacement clamps, featherweight forceps, collection form, pen or pencil, sharpie or grease pencil
Personal Protective Equipment: none required
Thoroughly check “stickum” for SHB. Remove samples with featherweight forceps and placed in vials of alcohol. Record any relevant data, such as date collected, trap number, etc. “Stickum” can be removed from samples with Histo-Clear II, but the solution destroys their ability to be tested genetically to determine if they are PSHB or KSHB. Replace trap and lure as necessary.

- Liter Bottle Trap

Service Liter Bottle traps in the same manner as Lindgren traps.

Surveys and Monitoring

Identification of SHB beetles and their associated host symptoms can be difficult and requires specialized training. A good introductory guide to identifying SHB, its symptoms, and potential look-alikes can be found at http://eskalenlab.ucr.edu/handouts/pshbsymplookalikeslandscape4252017.pdf

Samples

Drown all beetle samples in alcohol before transport. If possible, preserve samples in ethanol as other alcohols will degrade the genetic material in the sample. Tree tissue samples can be used to test for the presence of *Fusarium euwallaceae*, a fungal symbiont of SHB. Proper procedure for taking tree tissue samples can be found at http://eskalenlab.ucr.edu/handouts/howtosamplefliyer.pdf
Tree tissue samples can be transported in sealed plastic bags or other airtight container. Each sample should have a record of the GPS coordinates of where the sample was taken, the date of collection, the collector and corresponding contact information, what species the sample was taken from, and a description of symptoms. The submission form for Eskalen Labs can be found here
http://eskalenlab.ucr.edu/handouts/eskalen_lab_specimen_submission_form_01232017.pdf

Surveys

Surveys can be one of the quickest ways of determining SHB presence. A standard protocol for surveys of reproductive hosts should be set and held throughout the survey. Current common practice for measuring the severity of an infestation is by the number of entry/exit wounds (shot holes) present on a host. The severity is categorized by “Low” (<50 shot holes), “Medium” (50-150 shot holes), or High (>150 shot holes). Because of their massive reproductive potential, it may be necessary to inspect every host species in an area to determine if the area is free of SHB. Preferred hosts, such as trees in the genus’ Acer, Alnus, Platanus, Populus, and Salix, are more likely to show signs of SHB before less preferred hosts. While conducting a survey it is important to note the GPS coordinates of infected trees, level of infection, symptoms of infected trees, any types of samples taken, and weather condition at the time of the survey.
Unmanned Aerial Vehicles (UAV’s) also known as Drones can be used in areas with known infestations to identify heavily infested trees and stands of trees. Species known to exhibit signs of *Fusarium* Dieback can be spotted using UAV photography. This survey method has only shown to be effective at scouting heavily infested areas for further investigation. Use of UAV’s could disturb local wildlife, especially birds. If UAV’s are used for surveying, measures should be taken to minimize impacts on wildlife.

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