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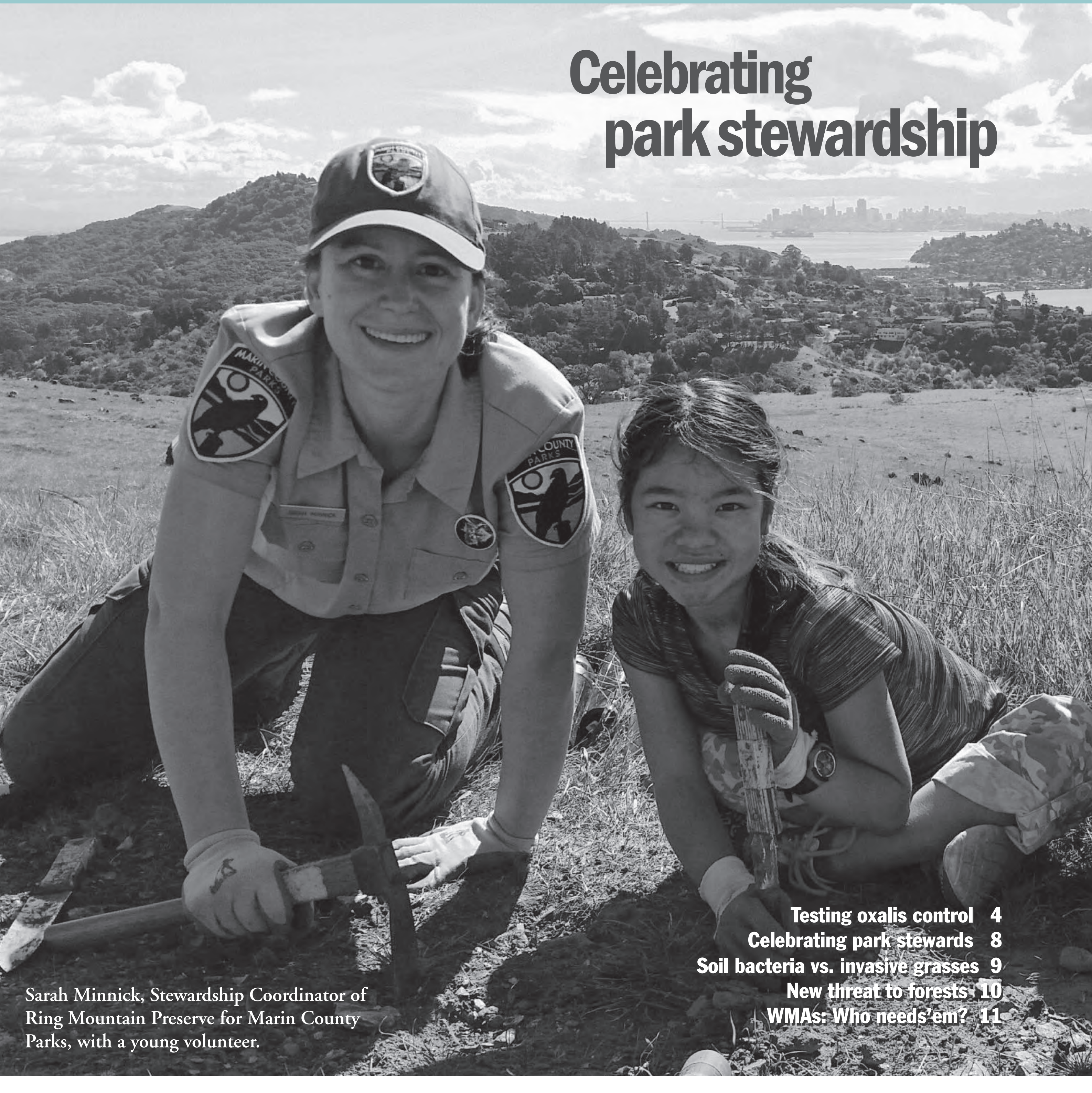

Sarah Minnick, Stewardship Coordinator of Ring Mountain Preserve for Marin County Parks, with a young volunteer.

New pest-disease complex threatens California forests

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Together with the avocado industry, land managers of native forest communities in southern California face the imminent threat of a new emergent pest-disease complex: *Fusarium* dieback – Shot Hole Borers (FD-SHB). Our work points to a path forward to make informed decisions on best approaches to management.

The beetle gallery in an infected tree.

Controlling emergent pests in the critical early stages of invasions is generally difficult because costly management decisions must be made with insufficient data. Which areas are most vulnerable to an infestation? How do invaders spread across a landscape? What management options are most effective?

Decision-making is further entangled when invaders spread across multiple land-use jurisdictions. Such uncertainty can cause delays and inefficient and ineffective use of resources. Our research team has developed an approach to reducing this uncertainty to confront FD-SHB with both short- and long-term control solutions.

A Complex Management Problem

The dieback is caused by the combined effects of two ambrosia beetles (the polyphagous and Kuroshio shot hole borers; PSHB, KSHB, both *Euwallacea* spp.) and the specific fungal pathogens each beetle carries (*Fusarium euwallaceae* and *Fusarium* sp.)

In 2003, a single PSHB beetle was caught in a California Department of Food and Agriculture trap in Long Beach. The beetle went unnoticed until 2012 when it was found damaging backyard avocado and urban forest trees in the Los Angeles basin. A rapid monitoring response uncovered the broad host range of the pest-disease complex, but its ability to establish in native vegetation was only gradually recognized.

Since 2012, these pests from Southeast Asia have killed or caused dieback of 41 tree species on which the beetles can reproduce, including 17 California natives (see sidebar, page 12). Another 262 species in 64 families are attacked but do not support beetle reproduction. However, they provide a substrate from which the beetle may find reproductive hosts.

This broad host range makes native riparian, oak woodland, and mixed evergreen communities highly susceptible to invasion and mortality by FD-SHB (Eskalen et al., 2013). By October 2015, FD-SHB infested over 280,000 native trees in the Tijuana River Valley in San Diego County, including arroyo willow (*Salix lasiolepis*), Goodding's black willow (*S. gooddingii*), and mule fat (*Baccharis salicifolia*) (see figure, pg. 13, Boland 2016). We continue to confirm FD-SHB attacking native vegetation in many new areas throughout San Diego, Los Angeles, Orange, and Riverside Counties (Eskalen and Lynch pers. obs.).

After the beetles leave, the *Fusarium* fungal pathogens continue to colonize the wood.

Ambrosia beetles, also known as shot-hole borers, interact with fungus to cause dieback of trees. *Photo by Shannon Lynch*

These particular plant communities are critical breeding habitat for endangered species such as the least bell's vireo (*Vireo bellii pusillus*), southwestern willow flycatcher (*Epidomax traillii extimus*) and arroyo toad (*Anaxyrus californicus*). As FD-SHB kills willows, cottonwood, and mule fat, it can make riparian habitats more susceptible to invasion by giant reed (*Arundo donax*) and saltcedar (*Tamarix* spp).

At these early stages of the epidemic, preventative and containment measures can fortunately still be effective, providing adequate, rapid assessment of key landscape factors.

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Current practices in avocado groves and urban forests rely on control measures such as systemic pesticides that are not generally appropriate for use in native habitats. Similarly, chipping infested wood to a size smaller than 1 inch, followed by solarization, kills the beetles, but it is not possible to cull trees that provide nesting habitat for endangered bird species.

An integrated pest management (IPM) program for native vegetation includes (1) developing tools to quickly detect new infestations and identify the beetles and fungi; (2) identifying which habitats are most vulnerable to FD-SHB and are most important in its spread; and (3) evaluating preventive and curative biological, mechanical, and chemical control options appropriate for different habitat types.

Early detection and rapid identification are critical. With two beetle species and at least two fungal pathogens involved in this pest-disease complex (Lynch et al. 2016), molecular tools to quickly and accurately identify the beetles and fungi are being developed to tailor control measures to the appropriate pest-disease complex (Stouthamer unpublished). Rapid identification tools are also essential for accurate mapping of the distribution of FD-SHB. But impacts and site-specific risk cannot be determined based only on where the beetles have already arrived.

Risk Assessment of Habitats

Effective management of an emergent pest-diseases complex requires predicting where it will spread and cause damage. We have begun a systematic survey throughout regional urban-wildland forests and agricultural lands, and are measuring vegetation and landscape characteristics, microclimate, and resident beneficial microorganisms across sites.

By combining these survey data with what we know about host range into an adaptive risk model, we can interpolate likely areas of spread into an interactive map tool to aid managers with decision-making.

Such early detection surveys and site-specific risk assessments help decision-makers focus resources in the face of insufficient data, and have reduced costs of management of invasive ambrosia beetles by 39% compared with no surveillance (Epanchin-Niell et al. 2014). This adaptive model, continuously improved with new survey data and field testing, will help prioritize management efforts to specific sites and avoid unfruitful efforts in low priority sites.

Controls in Development

Two approaches are being studied to effectively control FD-SHD. The first approach uses pesticides. Several systemic pesticides identified in preliminary field experiments show promise for controlling the beetles and fungi on individual trees if applied prior to infestation (Eskalen et al. unpublished data). Our landscape-based risk assessment will help reduce the environmental impacts of such pesticides by targeting their use as they continue to be tested and developed.

The second approach uses endophytes for biological control. Endophytic fungi and bacteria live inside plant tissues, and are analogous to the gut microorganisms that play a role in our own immune systems. We have already isolated several endophytes from local avocado and sycamore trees that escaped disease, and found they reduced the growth of the *Fusarium* pathogens. Our preliminary results additionally show that *Fusarium* spp. cannot colonize young avocado and sycamore plants inoculated with beneficial endophytes.

We are currently working with land managers to collect endophytes from additional surveyed native trees and test their biocontrol potential. We are conducting experimental trials to test if these protective endophytes can be inoculated prophylactically into seedlings and saplings of native plants to facilitate restoration of habitats and improve landscaping even where FD-SHB has become established.

Our risk model will be used to evaluate locations where resident endophytes may reduce vulnerability and where endophyte treatments may be most useful.

Native trees and shrubs affected:

Box elder (*Acer negundo*)

California sycamore (*Platanus racemosa*)

Red willow (*Salix laevigata*)

Black willow (*Salix nigra*)

Arroyo willow (*Salix lasiopeis*)

Cottonwood (*Populus fremontii*)

Black cottonwood (*Populus trichocarpa*)

Engelmann oak (*Quercus engelmannii*)

Valley oak (*Quercus lobata*)

Palo verde (*Parkinsonia aculeata*)

Mule fat (*Baccharis salicifolia*)

Big leaf maple (*Acer macrophyllum*)

Coast live oak (*Quercus agrifolia*)

White Alder (*Alnus rhombifolia*)

Blue palo verde (*Parkinsonia florida*)

Mesquite (*Prosopis velutina*)

Gooding's black willow (*Salix gooddingii*)

Summary

Appropriate management protocols for FD-SHB are contingent on a number of different landscape factors. Understanding these factors is time-sensitive and will result in long-term cost savings. Landscape assessments are urgently needed to provide managers with the information they need to prioritize use of limited funds. Individual stakeholder agencies can play a critical role by helping us document current impacts to better inform an integrated landscape risk model of the spread of FD-SHB. For updates and more information, visit *www.eskalenlab.ucr.edu* and *www.pshb.org*.

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