NEWSLETTER OF THE CALIFORNIA INVASIVE PLANT COUNCIL

Dispatch

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Protecting California's environment and economy from invasive plants

Cal-IPC Dispatch
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FROM THE DIRECTOR'S DESK

On the train

By Executive Director Doug Johnson

Amtrak's Capitol Corridor is my ride from Berkeley to Sacramento. Usually I'm headed there to advocate for county Weed Management Area (WMA) funding. But now we have WMA funding and I'm getting off the train in Vacaville for a meeting of the Solano County WMA. Recent weeks have also taken me to meetings of the San Mateo and San Francisco county WMAs and it's satisfying to see partners reconvene with purpose.

Along the East Bay shoreline between Richmond and Martinez we pass mudflats barely visible through the early morning fog. We're paced by a squadron of cormorants; didn't know they could fly that fast. The sunrise breaks through under the Carquinez Straits bridge. I think of the hardy Invasive Spartina Project team that heads out before dawn to catch the right tide for cordgrass treatment or Ridgeway's Rail counts. They see the bay up close and personal in a way few of us do.

The railroad right-of-way presents a thriving botanic gallery, native and non-native alike, toyon next to fennel, all testaments to the opportunism and vitality of vegetation in our disturbed landscape. Then we cut east across Suisun Marsh ("largest brackish water marsh on the west coast" according to Wikipedia), bringing visions of a Central Valley before dams, when the Sierra spilled its snowmelt freely into wetlands supporting vast clouds of waterfowl.

Not everyone looks at the California around them and sees what it was only a few centuries ago. "Nature's doing OK," someone said to me recently. (This was part of their rationale for why it was not important to use herbicides as part of an IPM approach for controlling invasive plants.) We need to remind our friends, family and colleagues that there is a global biodiversity crisis and we are responsible for caring for one of Earth's biodiversity hotspots.

Next stop, Fairfield/Vacaville. Time to get off the train and go be inspired by another WMA group!

On the cover:

Crews from Sage Environmental Group removed Canary Island St. Johnswort (*Hypericum canariense*) on City of Laguna Beach property with match funding from the Natural Communities Coalition through the Laguna Canyon Foundation. The Orange County Chapter of the California Native Plant Society (our 2019 Organization of the Year) identified and prioritized the spreading population, making this an excellent example of collaborative early detection and rapid response. Crews included a sawyer, followed by two swampers cutting and removing debris, and two applicators treating stumps with herbicide (diluted Garlon 4 Ultra with a penetrant applied with handheld Birchmeier spray bottles). An electric chainsaw reduced noise, creating less disturbance for nearby residents and allowing work during the city's quiet hours. A climbing rope was run from temporary anchors to aid movement on the steep slope. The inset photo shows a partially treated stand. Follow-up treatment the next year controlled new seedlings, occasional crown sprouts, and missed plants.

Photos courtesy of Sage Environmental Group and Laguna Canyon Foundation.

Wildland Weed News

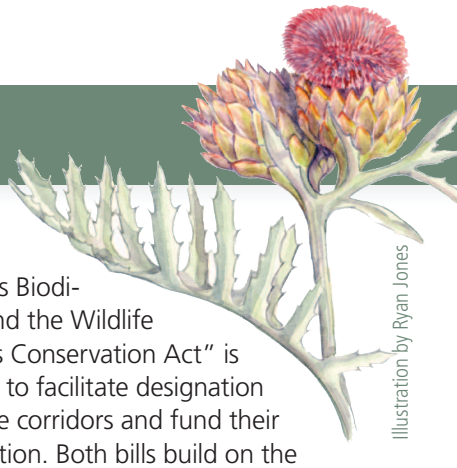


Illustration by Ryan Jones

CAL-IPC UPDATES

2019 Cal-IPC Symposium – More than 350 attendees came to Riverside to share the latest in ecology and management. Presentations are now online at cal-ipc.org/symposiaarchive. Article page 8.

Statewide WMA meeting – Reps from 23 WMAs attended the statewide meeting before the Symposium. We are working with WMAs as they prepare for a new round of grants. The California Dept. of Food & Agriculture (CDFA) plans to release the first round of new grants in early 2020.

New planning guide – Cal-IPC and the US Fish & Wildlife Service released a guide on planning your organization's invasive plant management. Article page 7.

Spartina partner – Cal-IPC is now a funded partner in moving the Coastal Conservancy's Invasive Spartina Project forward, working to remove stands of hybrid cordgrass from San Francisco Bay tidal marshes.

Cape-ivy biocontrol – After years of study and permitting, USDA ARS researchers are beginning to see evidence (new field galls) that the South African Cape-ivy galling fly is becoming established at several locations where it's been released along California's coast. Another Cape-ivy biocontrol agent, a leaf-mining moth, is still in the federal permitting process.

Riparian workshop – Cal-IPC sponsored the riparian restoration workshop held by RiversEdge West in Palm Desert, their first in California. Presentations are posted on their website.

OTHER NEWS

Tree pest threat – A study from Purdue University and the US Forest Service estimates that 41% of the live forest biomass in the US is at risk of future loss from 15 top nonnative insects and diseases. ("Biomass losses resulting from insect and disease invasions in US forests" in Proceedings of the National Academy of Sciences.)

Neonatives – An international team of invasive species researchers published "A conceptual framework for range-expanding species that track human-induced environmental change" in BioScience, addressing the conservation status of native species that expand their range into new areas because of anthropogenic disturbance.

Community science – The Audubon Society avoids using the term "citizen science" as part of their effort to make the conservation field more inclusive. www.audubon.org/about/equity-diversity-and-inclusion-audubon.

Tansy Games – In the first annual contest Del Norte County named Craig Strong its winner for bringing in 1,540 pounds of tansy ragwort. Overall, 16 teams brought in nearly 10,000 pounds for free disposal by the county.

Delta Symposium – Videos of talks are available online for the 2019 Delta Invasive Species Symposium focusing this year on remote sensing applications for management.

Change is hard – New Zealand professor Edy MacDonald spoke in Sacramento as part of the California Dept. of Fish & Wildlife's Conservation Lecture Series, discussing the role of behavioral science in stopping biodiversity declines. A video of the talk can be found on CDFW's YouTube channel.

Forb restoration – An online book at greatbasinfirescience.org has profiles on 18 forbs (with plans for five times that many) describing their use in restoration. A "revegetation catalog" is also available.

Federal wildlife bills – The "Recovering America's Wildlife Act" will increase federal funding to states for implementation of their wildlife action plans, while the "Saving America's Biodiversity and the Wildlife Corridors Conservation Act" is intended to facilitate designation of wildlife corridors and fund their conservation. Both bills build on the 2019 report on biodiversity decline by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.

Wetland weeds – A University of Illinois study examined two decades of data on dominant wetland plants, both native and non-native, finding that non-native plants reduced biodiversity more. *Ecology Letters.*

Congratulations to the 2019 Cal-IPC Photo Contest Winner, Julia Parish, for her picture of an American Conservation Experience worker hauling Arundo. *Take pictures now for the 2020 contest!*

Habitatittude – The campaign to address pet-owner awareness of invasive species, has been re-launched with support from the pet industry and federal wildlife agencies.

YOUR MEMBERSHIP

Thank you for keeping your membership current. Note that your expiration date is shown on the mailing label of this newsletter. Cal-IPC's success in meeting its mission depends on your vital support.

A weed on the move: Community scientists use iNaturalist to map the distribution of *Urospermum picroides*

C. Matt Guilliams, Kristen Hasenstab-Lehman, and Adam J. Searcy,
Santa Barbara Botanic Garden, Department of Conservation and Research

In 2019, the non-native plant *Urospermum picroides* (L.) F.W. Schmidt (Asteraceae), commonly known as prickly golden-fleece, went from here-and-there to everywhere in the City of Santa Barbara. Although localized expansion in Santa Barbara has been documented since the 1970s, the species appears to have rapidly expanded its non-native range in western North America as well as deepened its foothold in areas where it already occurred. When this seemingly sudden shift in range and density was detected in early 2019, a community science data gathering project was launched through the iNaturalist platform to document the species' current distribution and to increase public awareness of this heretofore mild-mannered plant of the Mediterranean region.

Lateral view of heads of (left) Urospermum picroides *showing single row of phyllaries and swollen receptacle and (right) of* Sonchus oleraceus*, showing multiple rows of phyllaries. Photos: Adam Searcy*

History of *U. picroides*

The earliest documentation of *U. picroides* in North America is an herbarium specimen gathered on the campus of the University of California, Berkeley in 1915 by Harvey Monroe Hall (s.n.; Carter 1960). The same population was later collected by Herbert Mason (s.n.) in 1943 and by Annetta Carter in 1960 (4109). A second center of distribution in California was documented with a collection by Clifton Smith (8655) in Santa Barbara in 1965. A third center of distribution was documented in Butte County with collections by Lowell Ahart beginning in 1985. In 2008, this species was highlighted in a Cal-IPC Weed Alert presentation as a potential species of concern. Cal-IPC subsequently reviewed the species but did not include in the Inventory because of insufficient information about its invasiveness and spread.

Santa Barbara Botanic Garden staff and colleagues began to take note of the species in Santa Barbara in 2017. Between 2017 and 2018, we found the plant sporadically occurring in low densities, often in disturbed settings such as roadsides, vacant lots, and occasionally trailsides near busy trailheads. In our experience, the species often co-occurred with other non-native Asteraceae like common sow thistle (*Sonchus oleraceus*), bristly oxtongue (*Helminthotheca echioides*), prickly lettuce (*Lactuca serriola*), and rough cat's-ear (*Hypochaeris radicata*).

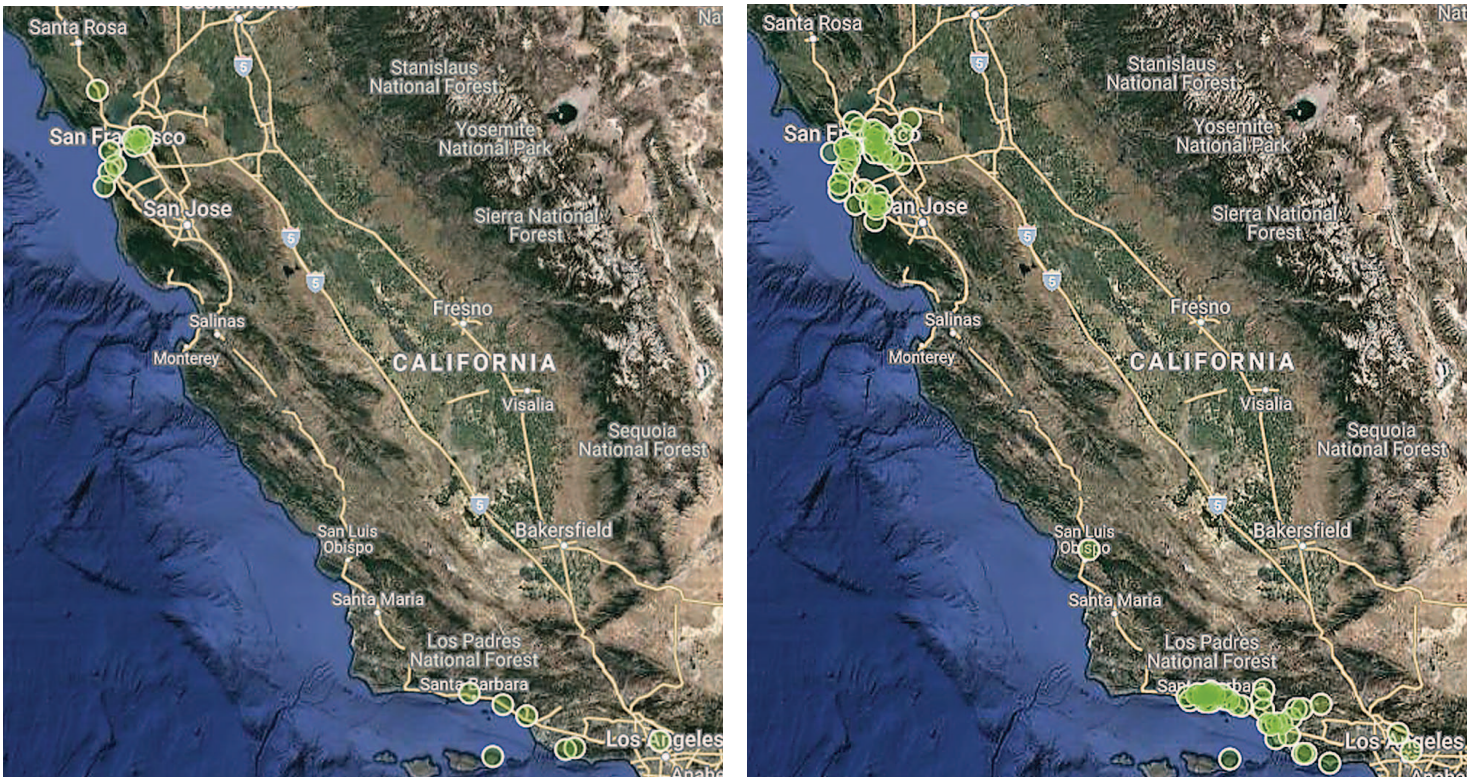
Lateral view of fruits of Urospermum picroides *showing 'tails' at fruit apex above flattened fruit body. Photo: Matt Guilliams*

Superficial similarity to these species may have served to mask the spread of *U. picroides*, but two sets of morphological characters can be used in the field to easily distinguish *U. picroides* from all other Asteraceae in western North America (and in fact, the world).

Identifying *Urospermum* in the field

Urospermum Scop. is a distinctive genus of only two species in the Tribe Cichorieae. The two species — *U. dalechampii* Scop. and *U. picroides* — are native to the Mediterranean Region. The former is a perennial herb with reportedly narrow habitat requirements; it has not expanded beyond its native range in historical times (except in Tasmania). The latter is an annual herb with somewhat broad habitat requirements and weedy tendencies; outside of its native range, it has been detected in North America, South America, South Africa, and Australia. Both *Urospermum* species are distinctive in having liguliflorous heads (heads of flowers with 5-lobed, "strap-shaped" corollas) and only a single series of phyllaries (reduced leaf-like structures that form one or more whorls immediately below a flower head) that are fused at their bases and are of approximately the same length.

There are a few differences in the flowerheads of *U. picroides* and its local weedy look-alike, common sowthistle, *Sonchus oleraceus*. *Urospermum* has a conspicuous, single row of phyllaries and a somewhat swollen receptacle, or flower head base. The flower head is typically armed with thick hairs but can also be hairless. *Sonchus oleraceus* has multiple series of phyllaries that are unfused and of uneven lengths. These differences in the



Maps from iNaturalist showing observations of Urospermum picroides *prior to (left) and after (right) project initiation.*

phyllaries alone are sufficient to distinguish between *Urospermum* and nearly all other weedy Cichorieae in California.

A second character pertains to the fruits and is unique to *Urospermum* in the Asteraceae globally. A hint is embedded in the name *Urospermum*, which derives from the Greek 'uro-' meaning tail, and '-sperma' meaning seed. The fruits of both species have a hollow 'tail' at the fruit tip. This distinctive tail is walled off from the chamber containing the seed. Combining the phyllary and fruit characters, the genus *Urospermum* can be confidently identified anywhere on earth.

Present-day distribution

We detected an increase in prevalence of *U. picroides* in Santa Barbara in early spring 2019 and launched an iNaturalist project to better understand its current distribution and to increase public awareness (www.inaturalist.org/projects/2019-california-urospermum-challenge). When the project was initiated, the species' North American range could be inferred from only 48 unique collection events in herbaria and 25 observations on iNaturalist. Between March 2019 and the present, 51 iNaturalist users have made 335 new observations, a 4 to 5-fold increase in the number of georeferenced data points for this species. As we suspected, the North American range of *U. picroides* was not accurately represented by herbarium specimens.

Through the iNaturalist project, users have documented many dozens of new localities, two new county records (Marin and San Luis Obispo counties), and one new country record (México). Potential range expansion aside, iNaturalist users also documented what appears to be increased densities within the known range of the species, both in the San Francisco Bay Area and Santa Barbara/Ventura counties. *Urospermum picroides* has not been documented in Butte County since 2003, so it is not possible to know if the species' range is expanding there or if it has disappeared.

While *U. picroides* appears to be becoming more common in western North America, it is still not yet clear whether the species will become a problematic weed here. We observed some roadside locations with high plant densities, but in many locations, plants remain in isolated patches. With greater awareness in future years, it will be possible to re-evaluate prevalence and rates of spread to more accurately assess the potential invasiveness of this species. Finally, while specimens in natural history collections such as herbaria remain the gold standard of documentation, we are excited about new tools like iNaturalist and Calflora that can greatly accelerate data acquisition and accessibility. Stay tuned for the iNaturalist 2020 California *Urospermum* Challenge!

Reference

Carter A. 1960. News and Notes. *Madroño* 15(7); 222-224.

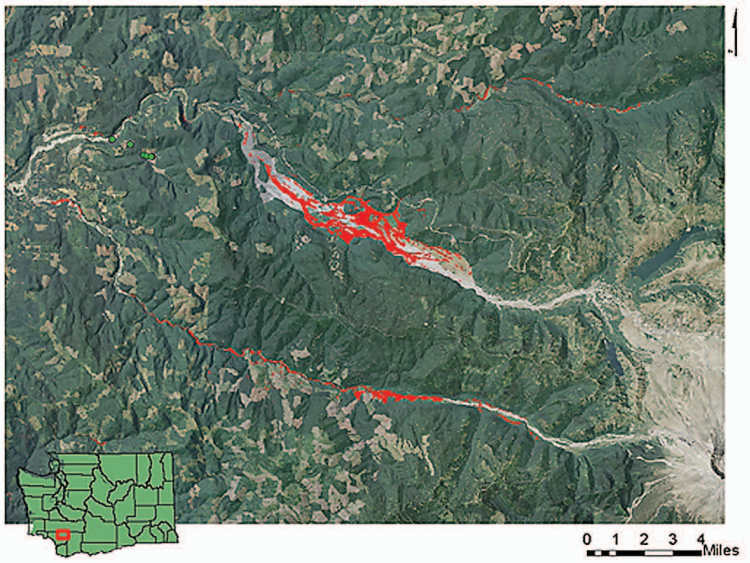
High-density roadside population of Urospermum picroides *in Santa Barbara. Photo: Matt Guilliams*

The cost of inaction: An example from the Toutle River

Traditionally, funding programs for weed management have used "acres of weeds treated" as a quantitative gauge of benefits. There are multiple problems with this as a metric when used outside an agricultural setting. It assumes that more area treated is better and that treatment itself is an end goal.

The goal of a wildland weed management is to cost-effectively reduce environmental impacts from invasive plants. While certain sites may require yearly maintenance efforts to protect valuable conservation targets (for instance, habitat for a listed species), projects with a start and an end aim to reach a new stable situation. The goal may be to remove invasive plants from an area and have native vegetation fill in the gaps. Or the goal may be to remove a population of an invasive plant species before it spreads. Funding programs need to develop appropriate metrics for better gauging the benefits of such projects.

Dense stems of invasive knotweed. Photo WSDA.



MaxEnt modeling output shows potential knotweed expansion in the Toutle River watershed. Map from WSDA.

One approach can be to quantify the cost of inaction. This can also be framed as "acres protected from future weed spread." Here is an example from the Pacific Northwest.

Knotweed on the Toutle River

Salmon recovery is a big focus in the region, for both environmental and economic reasons. Invasive knotweed is a threat to riparian habitat restoration for salmon recovery. Controlling knotweed across the state is led by the Washington State Dept. of Agriculture (WSDA).

WSDA used MaxEnt modeling software to predict places where knotweed is likely to thrive. The model uses current knotweed locations plus data on environmental factors such as elevation, rainfall, and soils. This helps them determine locations where knotweed is most likely to spread aggressively and impact salmon habitat restoration sites. These locations can be prioritized as a focus for using their limited resources for controlling knotweed.

The modeling can also help estimate the financial benefits of acting quickly when a small infestation has potential to spread. For instance, the Toutle River, which drains from Mt. St. Helens, has a relatively small infestation of knotweed. WSDA estimates that it would cost about $3,400 to control now, but if it is allowed to spread to nearby suitable habitat in the watershed costs jump to $150,000.

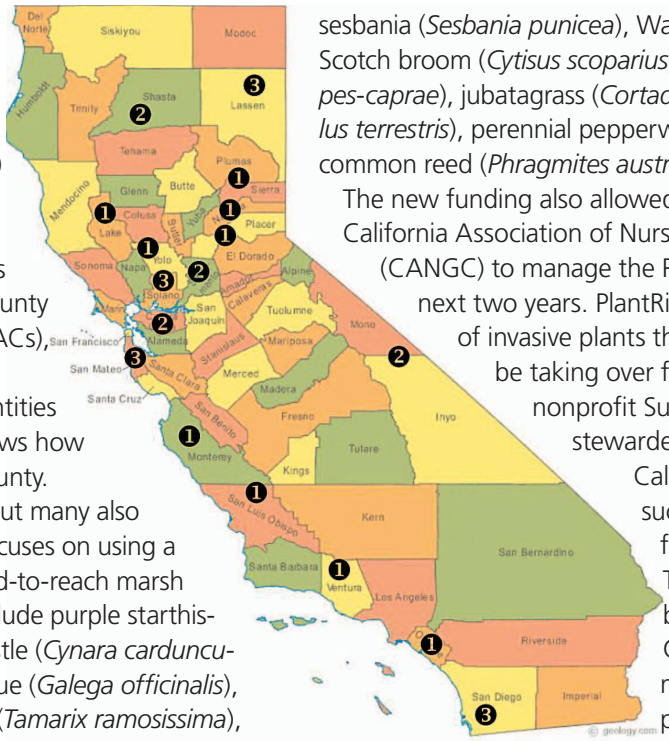
Increased cost can be a proxy for increased impacts, and dollars make a useful metric given that environmental benefits are difficult to quantify. Ideally, one has access to economic impact figures as well. In 2017, the State of Washington released an assessment of the economic impact of invasive species, estimating direct and indirect impacts at $1.3 billion annually based on 23 species, including $4.5 million from knotweed. (The report is available on the website of the Washington Invasive Species Council. See also Greg Haubrich's 2018 presentation in the Symposium archives on our website.)

Being strategic

Land managers need strong approaches to assessing the effectiveness and benefits of projects. How strategic is the project? How does it leverage resources to achieve sustainable conservation outcomes? Laying out the rationale for invasive plant removal in terms of finite investment to achieve long-term benefits to wildlife, water, recreation, fire safety or agricultural production is essential for demonstrating the value of such work to decision-makers and funders.

New state funding flows to county projects

State grants, 31 in all, have been made to counties for invasive plant management projects using $2 million dollars in funding secured by Cal-IPC in 2018 via AB2470 (Grayson). Funding came through the California Dept. of Food & Agriculture (CDFA). Projects cover 22 of California's 58 counties. Recipients included 11 County Agricultural Commissioners' offices (CACs), seven Resource Conservation Districts (RCDs), and two park districts (some entities received multiple grants). The map shows how many grants were awarded to each county.



Most projects are treatment-based, but many also include mapping and inventory. One focuses on using a drone for treating invasive plants in hard-to-reach marsh areas. Some of the species targeted include purple starthistle (*Centaurea calcitrapa*), artichoke thistle (*Cynara cardunculus*), giant reed (*Arundo donax*), goatsrue (*Galega officinalis*), knotweed (*Fallopia japonica*), tamarisk (*Tamarix ramosissima*), desert knapweed (*Volutaria tubuliflora*), spotted knapweed (*Centaurea maculosa*), barb goatgrass (*Aegilops triuncialis*), red sesbania (*Sesbania punicea*), Ward's weed (*Carichterra annua*), Scotch broom (*Cytisus scoparius*), Bermuda buttercup (*Oxalis pes-caprae*), jubatagrass (*Cortaderia jubata*), puncturevine (*Tribulus terrestris*), perennial pepperweed (*Lepidium latifolium*), and common reed (*Phragmites australis*).

The new funding also allowed CDFA to provide a grant to the California Association of Nurseries and Garden Centers (CANGC) to manage the PlantRight partnership over the next two years. PlantRight works to prevent the spread of invasive plants through horticulture. CANGC will be taking over for the San Francisco-based nonprofit Sustainable Conservation, which stewarded the program since 2015.

Cal-IPC's advocacy this year was successful in securing additional funding for weed management. The state's 2019 budget, which began July 1, puts $3 million into CDFA's Noxious Weed Management Account. This will be used primarily to support county Weed Management Areas (WMAs). Grants should be coming from CDFA in the spring.

Help is here for developing an invasive plant management plan

Jutta C. Burger, Cal-IPC Science Program Director

Anyone who has worked for very long in the field of invasive plant management knows first-hand that successful management is much more difficult than simply donning a pair of boots and setting out to wage war on the nearest weedy species. It is a complex process that is affected by many factors, including the unique landscape-level distribution and biology of each targeted species, local ecology and spatial parameters, human disturbance, year-by-year effectiveness of control measures, shifting external management priorities, and fluctuations in capacity and funding that, in turn, can impact previously set priorities. Our worst weeds further complicate matters with high reproductive rates, long-lived propagules and dispersal over long distances. As a result, our strategies need to be thorough, well-documented, and adapted over time in order to be effective.

If all that sounds so overwhelming that it makes you want to throw in the proverbial towel (or in this case, tool), help is here. Cal-IPC recently teamed up with the U.S. Fish and Wildlife Service and a panel of experts in the field to publish the Land Manager's Guide to Developing an Invasive Plant Management Plan to help land managers develop an effective plan for their organization. The guide lays out a step-by-step process for completing a plan, highlighting key issues that should be addressed along the way. It is available for free download through the Library section on Cal-IPC's website cal-ipc.org/BMPplanning.

By using the guide, we hope that you will be able to jump-start developing (or updating) your plan and include important elements that are often overlooked, such as: engaging stakeholders, creating a communication plan for upper management and the public, properly documenting baseline conditions and monitoring change, and clearly identifying the goals and the spatial scope of your plan. A template outline is provided to get you started, as well as a list of existing plans to refer to as examples (posted on the Cal-IPC website).

The guide highlights the importance of thoughtfully determining which species to address, why you are addressing them, where you are addressing them, and what are the underlying objectives of your program. By assessing existing information on each invasive plant's distribution and potential impact, you can prioritize appropriate types of management (prevention, eradication, containment, and asset-based protection) for different species and locations in a transparent manner.

To support adoption of the guide's principles, Cal-IPC conducted a well-

(Continued on page 14)

2019 SYMPOSIUM IN PHOTOS

In mid-October, more than 350 land managers, researchers, and volunteers gathered in Riverside for the 28th annual Cal-IPC Symposium. Our theme, "Evolving management perspectives in a changing world," featured plenary sessions exploring how ecological science continues to inform land management practice. Over four days, attendees shared the latest in invasive plant biology and management with talks, posters, training, discussion groups, and field trips. Here are some highlights!

Mark your 2020 calendars: Next year the Symposium will be at Chico State University, October 27-30!

Conservation corps members from several units in the region attended the Symposium, including a special lunchtime panel on careers in conservation. Photo: Claire F. Meyler

Dr. Arlee Montalvo of the Riverside-Corona Resource Conservation District received the Golden Weed Wrench Award for her years of dedicated work bringing research to bear on land management practice, especially revegetation with site-appropriate native plants. Photo: Claire F. Meyler

*Sunny Sameer (right), Lab Manager at the UC Riverside Dept. of Plant Biology, discussed studies at the Motte Rimrock Reserve evaluating the ecological effects of stinknet (*Oncosiphon piluliferum*) and management options for control. One study found that federally endangered Stevens kangaroo rats do not create their mounded burrows under the thickly matted stinknet plants and do not eat stinknet seeds. Photo: Claire F. Meyler*

Attendees consider their options at the Auction & Raffle fundraiser. Thanks to our generous donors and guests, we raised $5,000 for Cal-IPC's work. Photo: Claire F. Meyler

Benjamin Lambrechtsen from B&J Trading promotes the use of a new truck-mounted steam unit. More than fifty sponsoring organizations provided crucial support to the 2019 Symposium while reaching a broad cross-section of the land management community. Photo: Bill Hoyer

*Aaron Echols (in black cap), from the Inland Empire Resource Conservation District, leads a field trip along Mill Creek, a major tributary of the Santa Ana River. The canyon cut by Mill Creek runs through some of the tallest peaks in southern California and is surrounded by steep mountain ridges on both sides. Active watershed-wide control efforts are targeting tree-of-heaven (*Ailanthus altissima*), Spanish broom (*Spartium junceum*) and giant reed (*Arundo donax*) using physical and chemical approaches. Photo: Dana Morawitz*

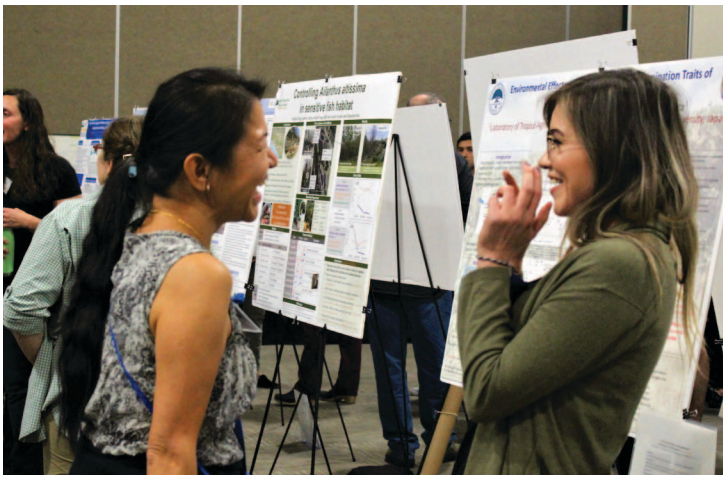
"We can all be mentors."

—Fabiàn Garcia in his acceptance speech for the 2019 Catalyst Award, speaking about the importance of taking action to usher new people into the conservation field.

Fabiàn Garcia, Director of the US Forest Service's Southern California Consortium, poses with his daughters after accepting the Ryan Jones Catalyst Award. He coordinates a program that provides environmental education and community outreach to connect underserved communities to nature and conservation work. Photo: Claire F. Meyler

Other award winners:

Joan Miller, volunteer extraordinaire with Orange County Parks, was our Volunteer of the Year. The Orange County Chapter of CNPS was our Wildland Stewardship Organization of the Year for their exemplary role in local invasive plant detection, management, and policy.



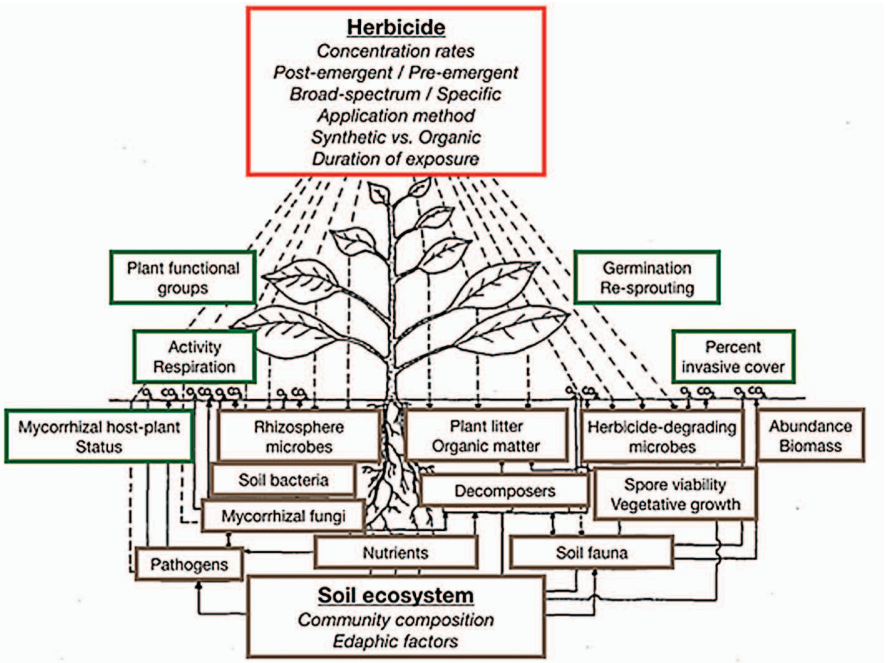
*Clarissa Rodriguez (right), from the Botany and Plant Sciences Department at UC Riverside, won first place in the student poster contest for her work comparing effectiveness of pre-emergent vs. post-emergent herbicides to control the spread of stinknet (*Oncosiphon piluliferum*). First place in the student oral presentation contest went to David Banuelas of UC Irvine for his study of Peruvian pepper tree (Schinus molle) soil effects on native understory plants. Photo: Claire F. Meyler*

David Garmon (left) accepted the Wildland Stewardship Policy Award on behalf of the Tubb Canyon Desert Conservancy for their work advocating for federal funding for biocontrol research to control Sahara mustard. David Bakke (right), recently retired from the USDA Forest Service, State and Private Forestry, received the Jake Sigg Award for Vision and Dedicated Service. He has been instrumental in supporting effective Integrated Pest Management (IPM) practices and in guiding efforts like the development of CalWeedMapper. Photo: Claire F. Meyler

Mind the microbes: Below-ground effects of herbicides used for managing invasive plants

V. Montellano[1], N. Rodriguez[2], L. Garcia[2], M.R. Maltz[2], E.L. Aronson[2]

Editor's Note: In recent years, presenters at the Symposium have shared studies on the impacts of invasive plant species to soil properties and organisms, and such impacts are part of the rating system used for Cal-IPC's Inventory. (Well-known examples are saltcedar increasing soil salinity and brooms increasing soil nitrogen.) Impacts of invasive plant management are critical to understand as well and we will continue exploring that topic at the Symposium and in Dispatch.



Components of soil ecosystems that can be affected by herbicide. *Schematic of herbicide effects, including plant and microbial parameters, on soil ecosystems. Herbicide may differentially influence soil ecosystems based on the concentration rates, types of herbicide, application methods, and the duration or frequency of exposure. Plant features (outlined in green) such as life history traits, functional types, community structure, activity, and mycorrhizal host status may determine the effectiveness of herbicide treatments, as well as impacts to soil biota. Soil edaphic factors and microbial communities (brown boxes) may experience shifts in community composition, functional attributes, abundance, depending on direct or indirect effects of herbicides on either biotic dynamics or abiotic inputs. (Modified from Edwards and Pimental (1989)* Critical Reviews in Plant Sciences 8.*)*

The belowground world of soil microbes is inextricably linked to aboveground communities (Wardle et al. 2004) and researchers are increasingly examining the relationship between the two. Controlling invasive plants involves a combination of methods including manual removal, mowing, cultivation, grazing, burning, and herbicides, all of which can have an impact on the soils. Throughout the process land managers work to take non-target impacts into account. A growing number of studies are focusing on effects on belowground organisms, such as mycorrhizal fungi.

This article focuses on the impacts of chemical control methods — herbicide application — and provides an overview of research on this subject. Though no clear recommendations have emerged for ways to adjust the use of herbicides in wildlands, this is a critical subject for land managers to track.

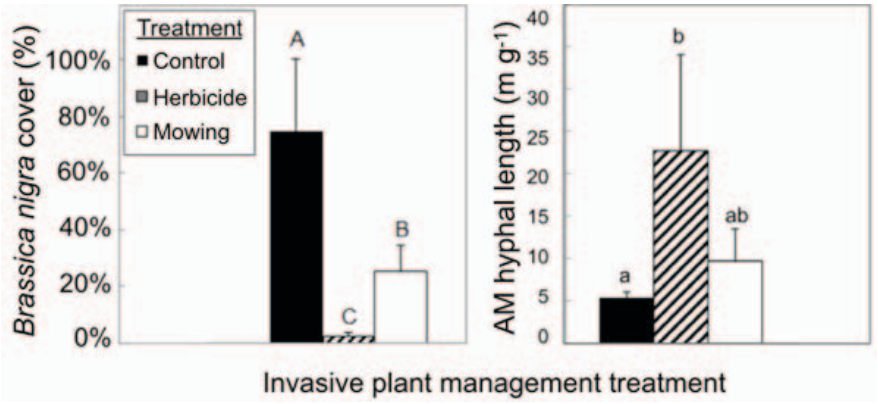
Herbicides vary greatly in their mode of action, their specificity, and their effectiveness, yet they all accomplish a similar goal: the destruction of plant tissue. Herbicides can have a large effect on soil microbes at the plant-root interface (the rhizosphere) because they often not only desiccate plant tissues above and belowground and alter a microbes' associations with their plant-hosts, but may also affect the soil biota by altering their chemical environment.

The most effective herbicides are systemic — they move from their point of entry in the plant to other parts of the plant, including the roots, when applied at the proper growth stage. These herbicides include broad-spectrum post-emergent synthetic herbicides such as those based on the active ingredient glyphosate. Glyphosate is one of the most studied herbicides, and we know a fair amount about its fate in the environment. As glyphosate breaks down within the ecosystem, it can produce aminomethyl phosphonic acid (AMPA) in both soil and water, which has been shown to have some level of toxicity to both macro- and microorganisms. Although the acute effects of glyphosate and AMPA toxicity on mammals are minimal, recent studies suggest that chronic exposure to ultra-low doses can secondarily influence soil edaphic factors (physical, chemical, and biological), the proliferation of plant and animal pathogens, and the composition of the soil microbial community (Van Bruggen et al. 2017).

Soil microbes perform a variety of ecosystem services (van der Heijden 1998), such as improving the establishment and success of native grasses and shrubs (Augé 2001) in degraded environments (Maltz and Treseder 2015). Weed control methods that desiccate plant tissues may directly affect microbes or indirectly impact root-associated mutualists, such as arbuscular mycorrhizal fungi

[1] Chapman University, Orange, California
[2] University of California, Riverside

(AMF), by killing AMF host plants. Previous studies have shown that glyphosate applications that reduce non-native plant cover correspond with lower AMF spore and fungal biomass (Zaller et al. 2014). Yet, when invasive plant management is combined with active revegetation that incorporates functionally redundant native plant species as superior AMF hosts (Johnson et al. 1993), these indirect effects could likely be ameliorated.



Treatment impacts on mycorrhizal fungi in the soil. *The graphs show (left) cover of* Brassica nigra *(black mustard) on a ground area basis and (right) fungal hyphal length of arbuscular mycorrhizal fungi (AMF) within mustard control experimental plots at the UC Irvine Ecological Preserve. Mowing treatments are indicated by white bars, herbicide treatments by shaded bars, and untreated controls by black bars. Treatment affected black mus¬tard cover (calculated from presence/absence data from 84 random locations within each plot) as well as AMF hyphal length calculated via microscopic analysis of stained hyphae. Bars are means +1SE of 2 UCI plots. Treatments with different let¬ters are significantly different from one another within sites (p < 0.05); whereas treatments with two letter are statistically equivalent to treatments labeled with any one of the shared letter (p > 0.05). (Modified from Maltz et al. (2016)* Ecological Restoration *34:209-215.)*

When degraded sites are invaded by plants that do not rely on AMF (i.e., inferior AMF-hosts or non-mycorrhizal plants), synthetic herbicide applications may positively influence AMF by opening up niche space for mycorrhizal-dependent native plant hosts. For instance, grow-kill management of *Brassica nigra*, a non-mycorrhizal invasive plant, with one annual glyphosate application following germination, reduced *B. nigra* cover and increased overall AMF fungal abundance relative to mowed treatments and untreated controls (Maltz et al. 2016). However, in the same study, a portion of fungal taxa which were abundant in the AMF community found in control or mowed plots were absent in glyphosate-treated plots (Maltz et al. unpublished data). These findings suggest that glyphosate treatment can affect not only the abundance of AMF found in degraded ecosystems, but may also exert an influence on soil microbial community structure. It is still unclear whether their effect is indirect, by affecting their AMF plant hosts, or direct, through chemical interaction with the fungal community.

In addition to influencing AMF, previous work indicates that herbicides can affect other microbial groups. Single doses of synthetic post-emergent herbicides may have no effect on soil bacterial and archaeal diversity (Dennis et al. 2018), or may even increase microbial biomass, ostensibly due to their ability to mineralize and use herbicide break-down products as an energy source (Kunch et al. 1985). Some studies have also shown that fungal pathogens may use herbicide as a fuel source. However, others suggest that herbicide exposure reduces pathogenic fungal growth (Rodriguez-Kabana et al. 1966, Leach et al. 1991). Spore germination and vegetative growth of a variety of microbes, including plant pathogen proliferation, can be affected, and may lead to increased disease incidence in cropland systems in some situations (Sanyal and Shrestha 2008).

Taken together, these studies indicate that the outcome of herbicide application may either stimulate or depress the growth rate of microbial populations or affect fungal diversity, depending on the type, formulation, or concentrations of chemicals, modes of application, and environmental conditions, as well as the specific microbial groups of interest.

In addition to soil fungi and bacteria, herbicides may also influence soil fauna, which play important roles in organic matter breakdown and nutrient cycling (Edwards and Pimental 1989, Deyn et al. 2003, Niemeyer et al. 2018). Some studies have demonstrated negative effects of high doses of post-emergent synthetic herbicides on soil invertebrates, as well as varied responses to a range of glyphosate formulations. In contrast, glyphosate use has been shown to have no effect on collembolans, nematodes (Dennis et al 2018), or earthworms (Santos et al. 2012, House et al. 1987).

Although herbicide often adds desiccated plant tissue into ecosystems, decomposition by microarthropods may be limited by increased herbicide exposure in some situations. Zaller et al. (2014) showed that glyphosate can interfere with earthworm-AMF interactions with leguminous forbs; these herbicide-driven effects may disrupt complex interactions throughout the soil food web. Responses to herbicide are context and dosage dependent and the setting and duration of exposure yield different consequences for belowground community interactions with soil fauna.

Organic herbicides

Post-emergent non-synthetic (i.e., organic) herbicides are often acidic or oil-based contact herbicides which could affect soil physicochemical properties, herbicide persistence, chemical solubility, nutrient availability, and organic matter decomposition (McCauley et al. 2009). Although organic herbicides are perceived as safer than synthetic herbicides for use in public places, they may pose risks to applicators and have largely unknown environmental effects.

Beyond a few studies in agricultural systems (DiTomaso et al. 2017), we have limited knowledge of the belowground effects of organic post-emergent herbicides in natural systems. A recent study examining the effects of organic herbicides on

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Reinvigorating indigenous land management: Amah Mutsun Land Trust and the Native Stewardship Corps

Alene Spindel, Cal-IPC Training Program Associate

The indigenous Awaswas and Mutsun speaking peoples have lived in and cared for the abundant coastal region called *Popeloutchom* for thousands of years prior to contact with the Spanish in the 1700s (known today as modern counties of San Benito, Monterey, Santa Cruz, Santa Clara, and San Mateo). Today, the Mutsun and Awaswas speakers are represented by the Amah Mutsun Tribal Band.

Mutsun and Awaswas villages spread across abundant lands of the San Juan Valley known as Tratrah and shared in tribal traditions and cultural practices. Ancestors of Amah Mutsun are collectively referred to by most as "Ohlone," though the Mutsun and Awaswas languages are distinctly unique within the Ohlone language family, as are their territories, religious practices, methods of fishing and hunting, ceremonial dress, craftsmanship, and shelter structures.

For thousands of years, the tribes cared for all living things in Popeloutchom as a right and responsibilty to the Creator. These rights and responsbilities were stripped from the Amah Mutsun during three periods of brutal colonization known as the Spanish Mission period, Mexican Period, and American period. Today's Amah Mutsun Tribal Band members are direct descendants of tribal groups who were removed from their territory and subjected to the Spanish at Mission San Juan Bautista (Mutsun people) and Mission Santa Cruz (Awaswas people). After three centuries of colonization and repression, today the Amah Mutsun Tribal Band (Tribal Band) has a mandated Tribal Constitution, Tribal Council, and a resilient community of more than 800 active tribal members.

In 2005, under direction of tribal elders, the Amah Mutsun began seeking to return to Popeloutchoum to fulfill their obligation to the Creator to care for all life. To reconnect and reestablish relationships to traditional territories and culture, the Tribal Band formed the Amah Mutsun Land Trust (AMLT) in 2013, which became a 501(c)(3) nonprofit organization in 2015. AMLT has reawakened tribal land tenure and developed partnerships with local state agencies and nonprofits to protect and steward tribal territories for the first time in hundreds of years. The mission statement declares, "These lands are the resting place of those that came before us and the cradle of those yet to come. They are sacred to us. Protecting their ability to sustain future generations is central to the mission of the Tribe."

Stewards spend two weeks per month working on land management projects and engaging in cultural learning. Photo courtesy Amah Mutsun Land Trust

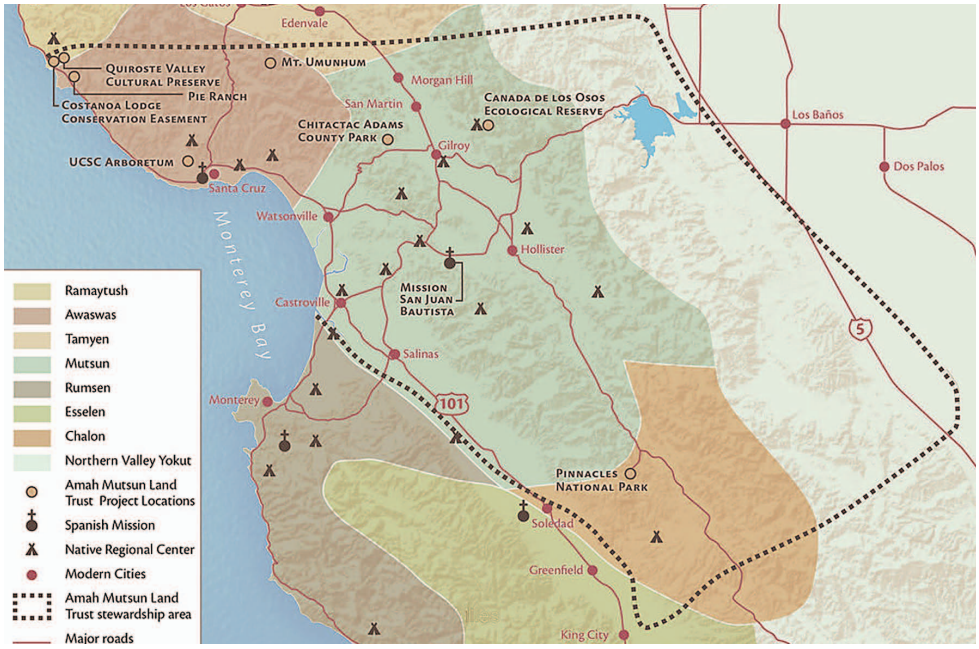
*The stewards are certified sawyers, seen here cutting down encroaching Douglas fir (*Pseudotsuga menziesii*) trees. Photo courtesy Amah Mutsun Land Trust*

AMLT has developed programs to re-engage tribal members in stewarding lands, relearning culture and language, and inviting the rest of the California community to be a part of this revitalization. The Native Stewardship Corps (the Stewards) is a program engaging young adult tribal members (18 years and older) in research, conservation, and cultural education to reconnect tribal members to traditional ecological knowledge, build professional skills for the field, and reinvigorate indigenous stewardship.

The Stewards program gathers 9 tribal members for two-week sessions of intensive land stewardship projects. Some of the Stewards are traveling from as far as Las Vegas and the Central Valley to work on projects on traditional lands. In order to reinstate indigenous stewardship on tribal territory, AMLT has developed partnerships with educational institutions, agencies, and nonprofits.

Sara French, Director of Programs and Development, says that ally support from conservation organizations and agencies are crucial to their success. Partnering with the Stewards through the Resource Conservation District, California State Parks provides consistent work and housing on-site, as well as hours of training in tool-handling, maintenance, and even sawyer certification. State Parks has also provided program funding and mentorship for participants.

The Stewards are now Red Card-trained firefighters. One of the future goals of the Native Stewards program is to increase fire work and restore cultural burning. Historical evidence shows that the Amah Mutsun have carefully tended landscapes, particularly the coastal prairie, with controlled burning as a land



This map, generated by the Amah Mustun Land Trust, identifies ancestral territories and the footprint of land stewarded by AMLT projects.

management practice. "These practices date back hundreds, if not a thousand generations," says Amah Mutsun Tribal Band Chairman Valentin Lopez. Chairman Lopez explained that the land management community today calls them "prescribed burns" but the tribe knows them as "cultural fires."

As of fall 2019, the Stewards are working on an ongoing project within Año Nuevo State Park in what was once an extensive coastal prairie. The Stewards are working in the valley cutting down thousands of Douglas fir (*Pseudotsuga menziesii*) trees to reduce fuel loads, placing trees in burn piles. Once the winter rains start, they will burn them safely with State Parks supervision. Chairman Lopez explains, "We teach the stewards how important these burns are to care for the fungi, the native plants, and the native animals — four-legged, invertebrates, and winged."

French explains that this is all part of the first phase of restoring this land. Stewards have been removing encroaching Douglas fir trees, jubata grass (*Cortaderia jubata*) and poison hemlock (*Conium maculatum*) each year. The larger goal is to restore regular burning to this area. Current steps include creating shaded fuel breaks, burn piles, making space for native grasses, and tending ethnobotanical species at the location.

The tribe hopes to expand the Stewards' capacity broadly in coastal resource stewardship. French wants land managers in the central-coastal region to know that the Stewards can be hired for land management work, and that, by doing so, organizations can help bring indigenous knowledge and leadership back to the land.

Says Chairman Lopez, "We have been relearning and reestablishing that relationship with Mother Earth. We are restoring that Indigenous knowledge and caring for the landscapes as our ancestors did. It gives us great pride and joy to return to that path, to honor our ancestors, and to fulfill our obligation. Our tribe is exceptionally proud of our Native Stewards. There is a waitlist of people wanting to be Stewards and follow this path of our ancestors. It is wonderful to see and is bringing healing to our Stewards and tribal members."

Learn more at amahmutsun.org and amahmutsunlandtrust.org

Mind the microbes

(Continued from page 11)

non-native annual grasses and soil bacteria showed that organic herbicide treatments had no effect on soil bacterial community composition (Maltz et al. unpublished data) relative to mowed and untreated controls. Unfortunately, the herbicides tested also did not significantly reduce the cover of mature seed heads of two weedy grasses being targeted, *Avena fatua* or *Bromus diandrus* (Swanson et al. unpublished data). Effects on soil or root-associated fungi, such as AMF, are not yet known.

Future studies on soil impacts in natural systems will be valuable for comparing: organic vs. synthetic herbicides; pre-emergent vs. post-emergent herbicides; invaded vs. restored ecosystems; and chemical vs. non-chemical approaches. Such studies could use biomarkers and molecular sequencing approaches to characterize the microbial community structure and function. Additionally, this could be coupled with microscopic analyses of percent root length colonized by mycorrhizal fungi for gauging belowground impacts. Such studies will be essential for better informing the restoration work of land managers.

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New planning guide

(Continued from page 7)

received training for using the guide at the 2019 Cal-IPC Symposium in Riverside. We hope the guide — and trainings based on the guide — will give land management professionals one more critical tool for their toolbelt to accomplish more effective invasive plant management and successful conservation outcomes into the future.

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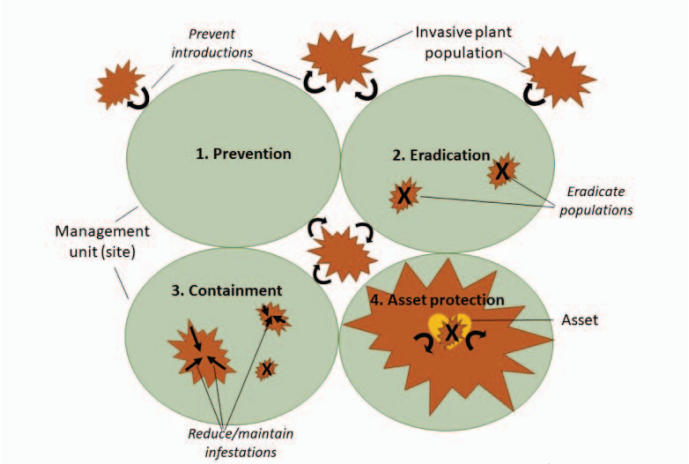

Landscape-level management strategies include: prevention (keeping out new infestations); eradication (fully removing all infestations in an area); containment (stopping the spread of a species); and asset protection (keeping a widespread weed out of a valued area). (Adopted from a diagram produced by Agriculture Victoria.)

Mind the microbes

(Continued from page 13)

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— Sir Robert Watson, Chair of the United Nations' Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), on their Global Assessment released in May.