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# Repelling Invaders

Photo: Jospeh A. Tosi, Jr.

## Hawaiian foresters use ecology to counter invasive species

*In the past 200 years, more than a thousand species of exotic plants have naturalized to the Hawaiian islands. More than 100 pose serious threats to native ecosystems.*

The Hawaiian Islands are one of the United States' most treasured natural resources. Their natural beauty attracts legions of visitors every year, and they represent a unique set of ecosystems. Despite their limited geographic size, Hawaiʻi hosts a remarkable range of habitats. On some islands, dry tropical forest, wet rain forest, and alpine ecosystems are found within 20 miles of each other.

The Hawaiian Islands are the most geographically isolated archipelago on Earth. Of the thousands of species native to the islands, 90 percent are found nowhere else. These native treasures are threatened by a host of invaders.

Researchers at the Pacific Southwest Research Station's Institute of Pacific Islands Forestry (IPIF), located in Hilo, Hawaiʻi, are working to understand how these exotics invade and degrade native forests. They are also developing biocontrol agents and management strategies to fight back against the exotic tide.

One of the most serious threats to Hawaiian forests is strawberry guava. This small tree, native to Brazil, was first introduced as a garden plant in the early 19th century. It is a close relative of common guava, an important commercial crop in Hawaiʻi grown for its sweet, musky fruit. Strawberry guava tends to form monocultures by spreading clonally through shoots and producing abundant seed. Pigs and birds disperse the seeds, allowing it to penetrate deeply into native forests. Once established, strawberry guava grows rapidly, crowding out native vegetation.

Another tree, the miconia (*Miconia calvescens*), is a garden ornamental that colonizes native forests and places where agriculture and development disrupt the landscape. It germinates and persists at very low light levels, allowing it to push through slight openings in the forest canopy and then shade out competitors. Its abundant seeds are spread by birds and mammals.

"It's a famous weed, at least in the tropical islands. Tahiti has pretty much been taken over by it," says Tracy Johnson, a research entomologist at IPIF. The plant is native to a wide range in Central and South America, though Johnson believes that Hawaiʻi's strain probably hails from Central America or Mexico.

Despite their potential usefulness, biocontrol agents are potentially hazardous. In the 19th century, the Indian mongoose was introduced to control rats in sugarcane plantations, but these small predators have since gone on to devastate native bird populations. In the mid-20th century, biocontrol agents introduced to control invasive blackberry also attacked a native Hawaiian raspberry. Strict regulations exist on biocontrol agents, which are extensively tested in quarantine facilities to assure their attack on the intended target. These requirements reflect a general change in attitudes toward introduced species. "People are sensitized now," says Johnson.

## Major Science Themes

**Exotic biocontrol agents:** Plants become invasive in part because they escape the animals, insects, and diseases that keep their population in check in their home range. To find biocontrol agents, researchers travel to the plant's home range and find agents that attack that plant selectively.

**Evolution in action:** Many insects evolve to specialize on one type of plant. They may be able to feed and reproduce on related species, but they rarely move to plants that aren't closely related to their natural host. That specialization is particularly helpful for controlling invasive plants with no native or commercially important relatives in the region, such as the velvet tree.

**Making themselves at home:** Invasive plants might modify their environment to their advantage. Fountain grass' spongy root systems soak up light summer rains, depriving nearby trees of a critical resource.

*Strawberry guava.*

Tectococcus *galls on strawberry guava leaves.*

**IPIF researchers strike back at the exotics that threaten to destroy Hawai'i's native ecosystems.**

With his colleagues, IPIF research entomologist Tracy Johnson is working to find an insect to control the strawberry guava tree. Their search has focused on its native range in Brazil, where insects have evolved to prey specifically on the tree.

"That's why it's an invasive species to begin with," he says. "It's a weed because it escaped its natural enemies—there's nothing local that is specialized to eat it."

The trick was to find an insect to feed and reproduce on strawberry guava, but spare the closely related, commercially important common guava. Since the trees grow close together in Brazil, it is possible to identify insects that feed on one tree but not the other. Field work by Brazilian entomologists yielded the insect *Tectococcus ovatus* (Brazilian scale), which is now in the final stages of approval for release.

Newly hatched *Tectococcus* nymphs settle on the strawberry guava's leaves, inducing the plant to build a bubble-like gall to enclose it. The damage is indirect. The tree uses energy to grow galls rather than new shoots, leaves, and fruit. The plant can develop quite a high density of galls on a growing tip, which can cause the tip to die or become severely stunted. "Based on what we've seen in Brazil, if you have a high enough density of galls on the tree… its vigor is reduced and it stops producing new fruit. Hopefully, we can stop it from spreading further," says Johnson.

Johnson expects that the biocontrol agent under development for strawberry guava will reduce fruit production, limiting the rate of spread. However, the scale could be combined with mechanical removal and herbicides that have been employed for years. Strawberry guava can be controlled by herbicides and cutting, but resprouts readily. "Managers of natural areas have to repeatedly revisit control sites. In some areas, they've been treating the same strawberry guava infestation for 8 or 9 years. We expect that *Tectococcus ovatus* will make the chemical and mechanical methods more effective because the insect will inhibit resprouting and reduce seed production," says Julie Denslow, who is a research ecologist and IPIF's team leader for invasive species

**IPIF researchers are also investigating the ecological processes that favor invasive species.** Plant physiological ecologist Susan Cordell and her colleagues study threats to dry tropical forests in Hawai'i. Characterized by intermittent dry seasons that alternate with rainy seasons, dry tropical forests at one time were probably the most extensive tropical

*Velvet tree, (*Miconia calvescens*) in full flower.*

Photo: Beth Reichert, McGill University

*Institute of Pacific Islands Forestry scientists are evaluating Costa Rican stem weevils* (Cryptorhynchus melastonae) *as a possible biological control agent for invasive miconia. Their research in Hawaiian quarantine facilities will determine whether the insect is sufficiently host-specific for eventual release.*

forest ecosystem in the world. That is, until humans adopted farming. "Because of their dry climate, they tended to be the first ones to (be cut down) for agriculture," says Cordell. Less than 10 percent of these ecosystems remain around the globe.

Water is the limiting resource for tree growth in tropical dry forests. Typically, species diversity in dry tropical forests is less than in tropical rain forests, but the plants are highly specialized to cope with limited water resources. However, Hawaiʻi's dry tropical forests are unusual. The diversity among canopy trees is much higher than in the canopy trees of Hawaiian rain forests. The canopies of most Hawaiian rain forests are dominated by two or three species. Dry tropical forests in Hawaiʻi may have 15 to 20 species of canopy trees.

Fountain grass (*Pennisetum setaceum*) is the primary species threat to dry tropical forests in Hawaiʻi, according to Cordell. A garden ornamental introduced in the early 20th century, it is too tough and spiny to be palatable to grazing animals, which has helped its spread: about 200,000 acres of forest have been converted, Cordell says. Cordell and colleagues have investigated the mechanisms behind the bunchgrass' takeover. Her team set up 20- by 20-meter plots where they removed fountain grass, and compared them to plots with fountain grass still in place.

She suspected that the invasive grass interferes with the ability of native trees to absorb summer rainfall. The dry tropical forest in leeward Hawaiʻi typically experiences light summer rainfalls of about 1 to 2 millimeters per day, barely enough to wet the soil. Still, Cordell suspected this constant dampening is crucial to sustaining the trees' productivity in the ensuing dry season. Fountain grass could be interfering with that because it maintains a thick, fibrous root structure that might outcompete tree roots for the limited water in the soil. To determine if this was indeed happening, Cordell and colleagues investi-gated the oxygen isotope content in the rain, soil, fountain grass, and nearby trees.

Oxygen isotope contents vary between cool (winter) season storms and summer storms, owing to the origin of the storm systems. Winter storms usually form some distance away from Hawaiʻi, while summer storms are usually local. Winter storms tend to have fewer heavy isotopes (180 and 2H) than summer storms because they form at lower temperatures (heavier isotopes are less likely to get swept up into the brewing maelstrom) and because heavier isotopes precipitate more easily, so the concentration is diminished by rainfall before the storms reach the Hawaiian dry forest ecosystems. By measuring the oxygen isotope content of the grasses, soil, and trees in their test plots, Cordell and colleagues could identify the source of the water in each system. During winter, they found that water from the heavier winter storms distributed evenly throughout the system. But in summer, the isotope analysis indicated that the trees were getting very little water. In plots where they had removed the grass, a similar situation occurred. However, after about a year, they identified a change in the dynamics. Tree roots began to take up more summer rainwater, and the trees grew at a 40 to 50 percent increased rate over the plots where the grass had been left in place. "It's a direct link between increased water availability and increased productivity," says Cordell.

The results reveal how fountain grass outcompetes native trees. "A lot of people think that grasses just take up cover, and that's why the forest doesn't regenerate," says Cordell. "Our approach has shown that competition for resources is also an important factor to consider. We've shown that the longer you have these grasses cleared, the more native regeneration you get. Unfortunately, you have to go in and clear them."

The results have implications for the timing of control efforts. Fountain grass doesn't reproduce vegetatively, and its seeds in the soil last only about 6 months. The seeds are only viable if the entire reproductive cycle—flowering, fruiting, and seed production—occurs during a single wet period. Most of the time, flowering occurs in response to a short rain, but is followed up by a drought and the seeds wind up sterile.

Proper timing of removal can greatly improve the odds of success. "If you can kill the grass during a period when the seeds aren't viable, then you gain at least a year (window) that you can get native plants in the ground for restoration," says Cordell.

*Dry Forest Working Group members at a recent Kaʻupulehu outplanting.*

## A Conversation with Julie Denslow, Research Ecologist

Q: ***Describe the Weed Risk Assessment Tool***

Developed in Australia and New Zealand to evaluate incoming plants, it basically lists questions that you ask about the species. The questions address factors such as: whether the local climate is suitable for the species—soil conditions, growing seasons, and so forth; the reproductive characteristics of the plant—if it has a short regeneration time, or produces small or large numbers of seeds; dispersal mechanisms—whether there are effective control techniques for the plants; whether it has particularly noxious qualities like thorns or toxins; and growth forms—vines and grasses are likely to spread more easily than trees. There are 49 of these questions and the plant is scored. In the end, you come up with a numerical index. If it's above 6, the plant is flagged as potentially invasive. If it's below 0, it's likely harmless. Scores between 0 and 6 are a gray area, where it's difficult to predict if the plant is likely to be a problem.

Q: ***How did you address that?***

Curt Daehler (a professor of botany at the University of Hawai'i) and I created an additional set of questions to evaluate this gray area, to help reduce it and push plants in one direction or the other. For example, we developed questions that would determine climate matches for Hawai'i. The climate is much different than what you find in New Zealand and Australia. So we adjusted those questions to meet Hawai'i's environmental conditions. The other questions are the same.

Q: ***How accurate was the updated tool?***

We addressed that question by asking a number of experts who were familiar with the islands. We talked to forest managers, nurserymen, agriculturalists—people with a wide variety of backgrounds. We asked them for their personal evaluation of various exotic plants, whether they were problems or not and under what circumstances they caused problems. We found that it performed well, correctly predicting 95 percent of major pests and 85 percent of nonpests.

Q: ***What's next for the Weed Risk Assessment Tool?***

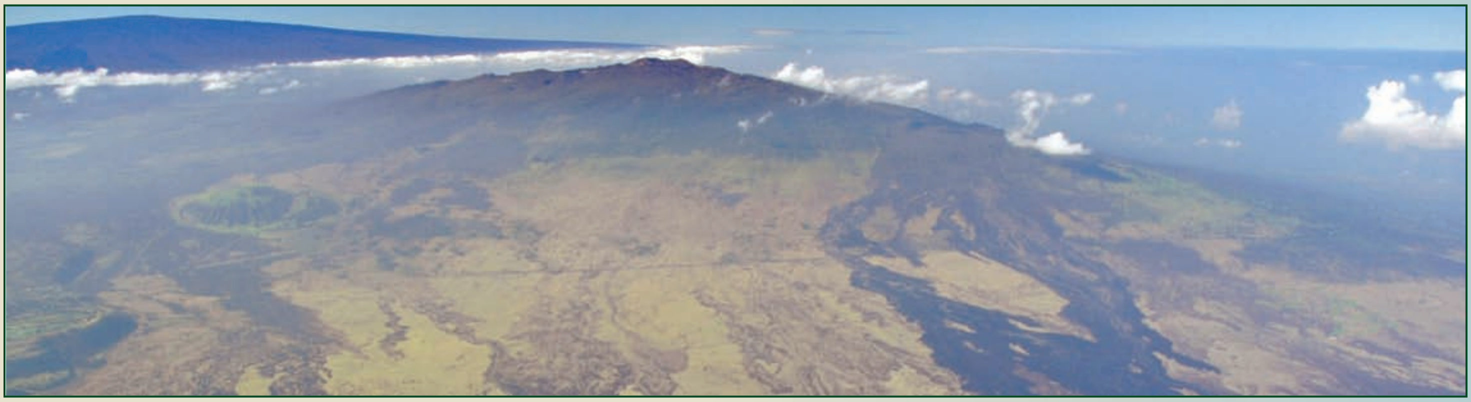
It has been evaluated in a number of different countries and is now under consideration by quite a variety of places for use as an official screening tool (to prevent import of plants likely to become invasive). It's officially used as a preintroduction screen for Australia and New Zealand, where it was originally developed, and is under consideration as a management tool in Florida, California, Canada, and the Czech Republic, among other places.

## Management Implications

**Timing is everything:** Invasive species may have periods of low reproductive success that may be an ideal time to remove them. Fountain grass seeds produced during intermittent rainy periods are usually nonviable, so removal during those times can maximize the chances of native plant recovery.

**An ounce of prevention:** Some plants are just inherently more invasive than others for a variety of reasons. The Weed Risk Assessment Tool was designed by researchers in Australia and New Zealand to identify potentially invasive plants and to prohibit them from being imported. A modified version of the tool is helping researchers understand invasive species in Hawaii'i, and it could be employed in other parts of the United States.

Hibiscus brackenridgei — *Hawai'i state flower — now an endangered species found in relatively dry ecosystems.*



*Aerial view of Pu'u Wa'a wa'a Experimental Tropical Dry Forest.*

# Scientist Profiles

**Julie Denslow:** Research ecologist and scientist emerita. (808) 933-8121 ext. 118, jdenslow@fs.fed.us.

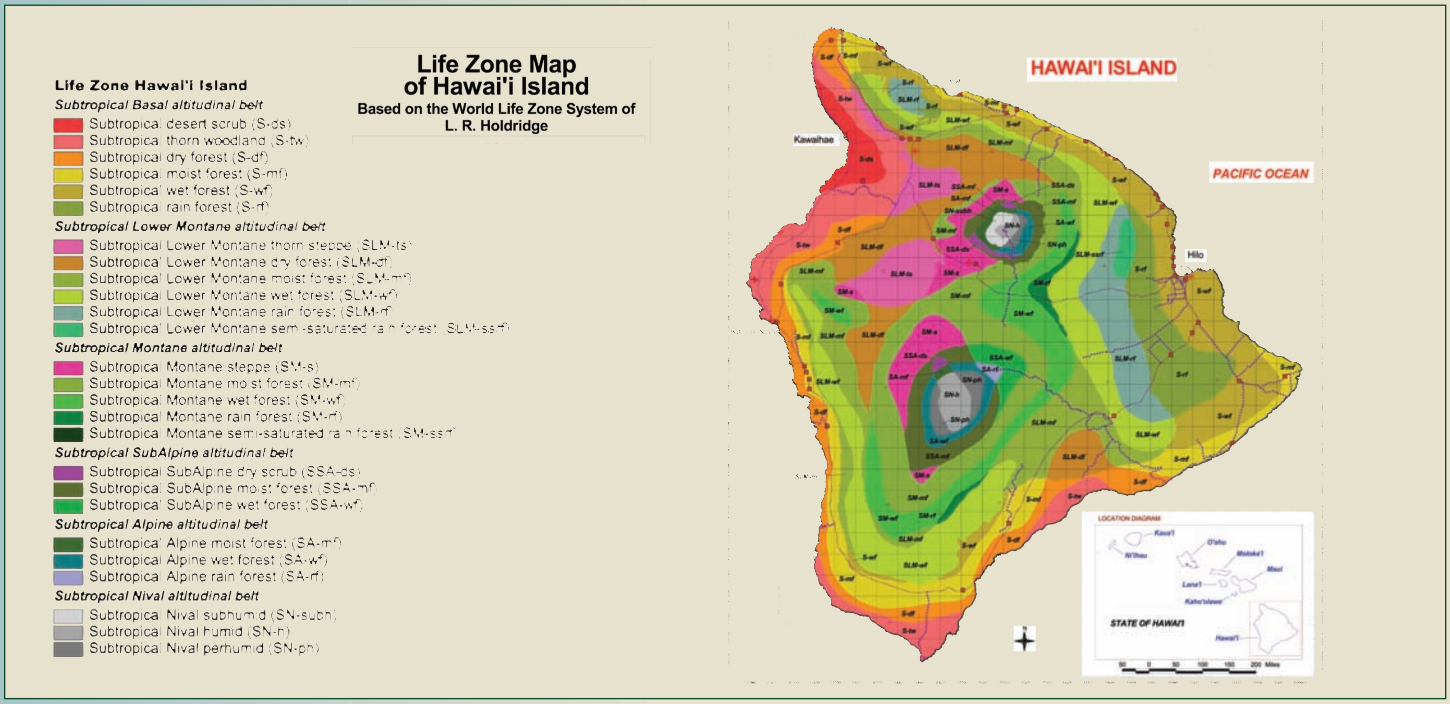
**Julie Denslow** received a Ph.D. in botany from the University of Wisconsin in 1978. Her research interests include the ecology of invasive exotic species; risk assessment and cost/benefit models for invasive species; and population, community, and ecosystem processes associated with disturbances to tropical and warm temperate forests. Her current projects include growth rates and physiological characteristics of Hawaiian trees and shrubs economic and ecological assessments of the invasive strawberry guava tree; the demography of the strawberry guava in mid-elevation moist Hawaiian forests; and the impact of the biological control agent *Colletotrichum gloeosporioides v. miconieae* on the invasive velvet tree.

**Tracy Johnson:** Research entomologist. (808) 967-7122, tracyjohnson@fs.fed.us

**Tracy Johnson** received a Ph.D. in entomology from North Carolina State University in 1995. His research interests include the biological control of weeds; insect ecology; postrelease monitoring of biocontrol agents; non-target impacts of biocontrol; and plant-herbivore-enemy interactions. His current projects include the development of insect agents from Brazil, Costa Rica, and China for biological control of weeds in Hawaiian forests; evaluation of non-target interactions between native Hawaiian plants and weed biological control agents released in the past; and methods for avoiding interference between biological control agents and natural enemies already present in Hawai'i.

**Susan Cordell:** Plant physiological ecologist. (808) 933-8121 ext. 128, scordell@fs.fed.us

**Susan Cordell** earned a Ph.D. in botany from the University of Hawaii'i in 1999. Her research interests include ecophysiology, restoration ecology, functional ecology, tropical dry ecosystems, grass invasions, and Hawaiian ecosystems. Her current projects focus on ecosystem-level impacts of invasive grasses on Hawaiian dry forest ecosystems; mechanisms by which fountain grass limits Hawaiian dry forest native plant establishment and growth; functional ecology and phenology of dry forest canopy trees; the role native plant reforestation plays in reducing fine fuel load hazards; reversing the cumulative adverse ecosystem-level effects of monotypic stands of invasive grasses in leeward Hawai'i; and impacts of invasive species on lowland forest ecosystem processes.




Map: Tosi, J., Watson, V., Bolaños, R.

## What's Next

Results in Hawai'i are watched closely by other tropical islands.

"Most Pacific islands don't have the research infrastructure to provide the biocontrol information that they need," says Denslow. Tahiti has a keen interest in the outcome of the velvet tree biocontrol research.

"They don't have a good biocontrol infrastructure, so they're very interested in what we're developing." says Johnson. "The history of biocontrol has a lot of that kind of transfer. If an agent is successful in one area, it is often transferred."

**Writer's Profile: Jim Kling** is a science writer based in Bellingham, Washington. His work has appeared in *Science* magazine, *Scientific American*, *Technology Review*, and other publications. Ecology is often an important theme in his science fiction stories, which he has published in *Nature*.

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