



A firefighter stands by as molten lava seeps through the forest. Credit: Hawai'i Volcanoes National Park.

## Fire and Rain: Stemming the Tide of Invasive Plants in Hawaiian Ecosystems

### *Summary*

In the rainforests of Hawai'i, wildfire is an uncommon occurrence, and repeated wildfires in the same area rare indeed. In 2002 and 2003, successive lava-ignited wildfires in Hawai'i Volcanoes National Park burned from seasonally dry to mesic low elevation plant communities to higher elevation rainforests, causing 95-percent mortality of the canopy. The lower elevation communities consisted of native shrubs in the overstory and invasive, non-native grasses and ferns in the understory. In the mid-elevation forested communities, non-native sword fern dominated the understory, while the higher elevation communities consisted of native trees in the canopy and native ferns and tree ferns in the understory.

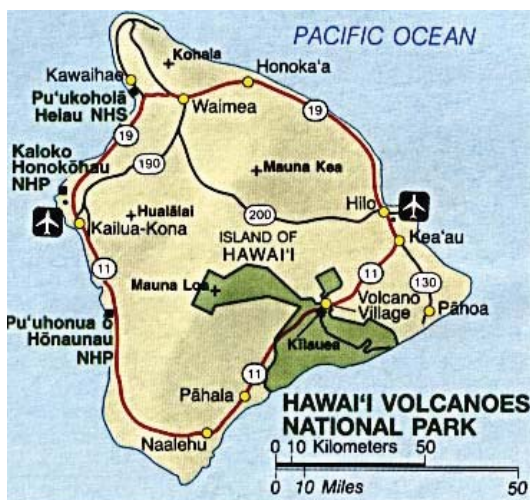
In the aftermath of these fires, park managers and researchers were concerned about the effects of fire on native plants and the role fire plays in encouraging the spread of non-native vegetation. Researchers measured the effects of successive wildfires on native and alien vegetation in shrubland and forest communities along an elevation/rainfall gradient. They found that, while native plants can recover after fire, after successive fires, non-native species rebound more aggressively, threatening the recovery of native vegetation. Non-native ferns in particular are encroaching on the higher elevation rainforest where they had not previously been observed.

## Key Findings

- In Hawai'i Volcanoes National Park, three lava-ignited wildfires in close succession, in 2002 and 2003, set the stage for unprecedented studies on the effects of fire on native and non-native plant species.
- Even after repeated fires, many native species were able to recover, primarily by sprouting from roots or by propagating from seeds or spores, but fire-adapted non-native species bounced back with greater vigor.
- At higher elevations, non-native vegetation in the rainforest understory may compromise the ability of the dominant native tree, the ohī'a, to recover after fire.
- At seasonally dry lower elevations, fire in the shrub-dominated communities had little effect on the vegetation that had been previously modified by past fires and non-native vegetation.
- In fire prone areas, it is impractical, if not impossible, to completely eliminate non-native plants and return the landscape to its historic condition, but research is helping identify fire-tolerant native plants that can hold their own against non-native species in an altered fire regime.

## Rare ecosystem

The islands that form the Hawaiian archipelago were born of millions of years of volcanic activity, and volcanoes continue to alter the landscape today. Among the most active volcanoes on Earth, Kilauea, is located on the Big Island of Hawai'i, in Hawai'i Volcanoes National Park. Each year, more than 2.6 million people visit the park, which was established in 1916 and designated in 1980 by the United Nations Educational, Scientific and Cultural Organization (UNESCO) as an international biosphere reserve.



Credit: University of Texas Libraries.

In addition to the attraction of volcanoes and lava flows, visitors are drawn by the flora and fauna of the park. More than 90 percent of the species of the Hawaiian archipelago are unique to the region, and species richness—that is, the number of endemic or native species—is small. “Because this is the most geographically remote archipelago in the world, the only way an organism could get there was through the air currents, or floating on water, or carried by birds,” says Rhonda Loh, acting chief of the park’s natural resource division. “Only a small subset of continental species made it—birds, insects, and plants—and virtually no four-legged animals.”

In the absence of many of the threats common to continental flora and fauna—such as predators, grazing animals, and disease—the Hawaiian biota evolved into unique organisms. “Many have lost their ancestral defenses,” says Loh. Raspberries lost their thorns, for example, and aromatic plants such as mint lost their repugnant, and protective, odor.

Moreover, humans were latecomers to the islands. The first wave of Polynesian settlers arrived barely 2,000 years ago. For that reason, the fire regime of the Hawaiian Islands is fundamentally different from the fire regime of the continents, with their long history of anthropogenic fire. Before the early settlers arrived, bringing with them about 25 species of plants such as taro, banana, and coconut, and domesticated animals such as pigs, dogs, and chickens—and accidentally, rats—the only source of fire was lightning or lava flows. The settlers used fire to clear forest land for their crops.

*...the fire regime of the Hawaiian Islands is fundamentally different from the fire regime of the continents*

Despite extensive alterations of the landscape by the earliest settlers and by Europeans who arrived in the 18<sup>th</sup> century, large tracts of rainforests remain on the islands of Hawai'i. These native dominated areas were perceived to be relatively immune to wildfire. In contrast, dry and mesic forests have been increasingly subjected to invasion by non-native species, many of which evolved in a regime of frequent fires. These vegetative species, which include fire-adapted grasses and alien ferns, are dramatically altering the fire regime and represent a growing threat to the native vegetation of the island in general and Hawai'i Volcanoes National Park in particular. Dealing with these threats is a high priority of park managers.

## Unprecedented wildfires

The prehistoric, long-term history of fire on the islands of Hawai'i is poorly understood for a number of reasons. For one, in tropical climates trees grow year round and thus do not develop tree rings, which are used in temperate climates to establish the chronology of weather and fire phenomena in the absence of written records. It is therefore unclear to what extent native vegetation has

either evolved with, or adapted to fire. Other disturbances that have likely shaped the evolution of native plants include landslides, lava flows, and storm events such as strong gales and hurricanes.

In tropical rainforests, wildfire is a relatively rare

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occurrence, and recurrent wildfire in the same location even less common. Successive, lava-ignited wildfires in 2002 and 2003 in Hawai'i Volcanoes National Park, on the southeastern coast of the main island of Hawai'i,

burned large areas of shrub and forest land that included rainforests and raised the level of concern for the survival of native vegetation.

In May 2002, lava flowing from the East Rift of the active volcano, Kilauea, ignited fires from low elevation seasonally dry to mesic grass and shrub land to higher elevation rainforest. The fire lasted 19 days and eventually consumed about 3,800 acres (1,538 hectares). Unusually low humidity and higher than normal winds contributed to the severity and extent of the fire, which destroyed 95 percent of the canopy.

The following year, two more lava-ignited wildfires burned in the same general area. In January, the Panauki fire burned 2,125 acres (860 hectares) of seasonally dry low- to mid-elevation land, from 196 to 2,198 feet (60 to 670 meters) in elevation, and in May, the Luhi fire, burned across a mesic to wet gradient, from 1,300 feet to 2,800 feet (396 to 853 meters) in elevation.

## Winners and losers

After the fires of 2002 and 2003, researchers from the Park Service, the Forest Service, and Oregon State University conducted studies to determine the effects on native and alien plants. The goal of the research, funded in part by the Joint Fire Science Program, was to determine the response of native woody species to lava-ignited wildfires, to assess the effects of fire on native and nonnative species across the entire gradient and in different plant communities, and to assess the response of native and invasive species in higher elevation rainforests to successive, severe wildfires.

Experimental plots were established on five vegetative communities ranging from low elevation seasonally dry shrubland to high elevation rainforest. Two native species, the ohia tree and the a'ali'i shrub, are dominant in the overstory across this elevation range, with a'ali'i predominant at lower elevations and ohia predominant at higher elevations. Both are widely distributed, hardy, well adapted to a wide range of microhabitats, and historically important to Hawaiians.

The ohia lehua (*Metrosideros polymorpha*), is one of the most revered plants in Hawai'i. Ohia refers to the tree, lehua to the blossom, which is used in crafting the traditional lei. Ohia is one of the first plants to establish on recent lava flows. The genetic plasticity of the ohia has allowed it to adapt across the entire elevation gradient of the island up to subalpine habitats, and to thrive in

arid to wet environments. A very slow-growing tree, at maturity it can attain heights up to 80 to 100 feet (24 to 30 meters). Photographs taken in the late 1960s, prior to a wildfire that burned in 1972, show open woodlands at lower elevations consisting of ohia trees along with mixed shrubs and understory. Today, the ohia tree represents less than 1 percent of cover in the lower elevation shrubland communities and up to 60 percent at higher elevations.

The a'ali'i (*Dodonaea viscosa*), like the ohia, demonstrates a wide variety of adaptations to the variable microhabitats of the islands. It too is found as an early colonizer of lava flows, and it ranges from nearly sea level to the higher elevations up to 7,500 feet (2,286 meters), in conditions ranging from arid to wet. It can grow as tall as 26 feet (8 meters), but usually ranges from 6 to 12 feet (2 to 4 meters). It is known as the shrub that can resist the strongest gales without bending and therefore is a symbol of toughness in the face of adversity.

The two a'ali'i dominated communities have a recent history of fire and of invasion by fire-adapted non-native vegetation. At the seasonally dry lower elevation, the native a'ali'i shrubland has been invaded by an understory of nonnative, perennial bunch grass, broomsedge (*Andropogon virginicus*), which was introduced in the 1960s as pasture for domesticated cattle, sheep, and goats. Broomsedge is fire adapted and thrives in the tropical climate, with no dormant season to slow its spread. At the second gradient, the fire-adapted sword fern (*Nephrolepis multiflora*) has invaded the understory.

At higher, wetter elevations, shrubland gives way to tree dominated communities. At 1,204 to 2,100 feet (550 to 640 meters), ohia trees dominate the canopy with sword fern predominant in the understory. At 1,200 to 2,460 feet (640 to 750 meters), the understory consists of uluhe (*Dicranopteris linearis*), a native fern that forms a dense mat on the forest floor. At the highest elevation, from 2,297 to 2,789 feet (700 to 850 meters), the understory is dominated by the native Hawaiian tree fern, hapu'u pulu (*Cibotium glaucum*).



Hapu'u, Hawaiian tree fern (*Cibotium glaucum*) survival after fire in the understory of higher elevation rain forest. Credit: Boone Kauffman.

As part of work towards her masters' thesis, Alison Ainsworth, a student of Boone Kauffman's at Oregon State University at the time, established plots in burned and unburned (control) sites across five different vegetative communities. Ainsworth, a natural area reserve specialist with the Hawaii Division of Forestry and Wildlife, and colleagues with the Forest Service and the National Park Service found that 19 native woody species of trees, shrubs, and tree ferns survived after fire primarily in two ways, vegetatively, by sprouting new growth from the base of the plant, and by establishing from seed after fire, in the soil bank or from nearby unburned areas.

In the higher elevation ohī'a dominated rainforest, despite top-kill of the canopy, more than half of the trees rebounded via basal sprouting, though the smaller diameter trees responded more vigorously than the larger trees. Although the ability of woody species to survive repeated fire is encouraging, Ainsworth cautions that increased competition from non-native plants may compromise the ability of native species to recover in an altered fire regime.



Researchers Mychael Tetteh and Liz Band monitor vegetation response after repeated fires (2002 and 2003) in the tree fern wet forest. Credit: Alison Ainsworth.

A second study followed changes in composition of vegetation for two years after lava-ignited fires across an elevation and plant community gradient from the lower elevation seasonally dry shrubland to higher elevation rainforest.



Despite topkill of the canopy, nearly half of the ohī'a lehua (*Metrosideros polymorpha*) trees sprouted from the base following fire across the study area. Credit: Alison Ainsworth.

In the two lower elevation shrubland communities, which were already invaded by broomsedge and sword fern, fire caused little change in the understory vegetation or shrub canopy. These two communities had previously burned in 1972 and 1992. "The two shrubland communities

had a history of fire and recovered rapidly," Ainsworth says. Moreover, there was no evidence of young native trees regenerating after the fires, indicating that these communities have been altered, perhaps permanently, by the combination of recurrent fire and invasive plants.

In the lower elevation forested community where sword fern has become established in the understory, the ohī'a tree was able to reestablish after the fires, but sword fern also recovered rapidly. At the next higher elevation ohī'a forest community, the uluhe was much slower to recover. "The fire left large areas of a thick litter layer that is slow to decompose," Ainsworth says. "After two years, we can only guess what will happen when it finally decomposes, but it will probably be invasive plants that establish."

At the highest elevation, 90 percent of the tree ferns in the understory survived successive fires. "The fronds were burned but the ferns resprouted." Where the litter burned off, however, "we found non-native grasses under the tree ferns."

"We found that the native plants survived, but aliens also survived and rapidly colonized the burned areas," Ainsworth says. "Our hope with this study was to determine which areas in the future should be the highest priority for protection."

Ainsworth and colleagues also examined changes in the vegetative community in the two highest elevation, ohī'a dominated, rainforest communities that burned in 2002 and 2003. These wet tropical forests had not burned before, and their understories were dominated by uluhe and Hawaiian tree fern.



Researchers John Boerner and Sally Madden quantify fuel loads and species diversity in an unburned uluhe wet forest site. Credit: Alison Ainsworth.

While 75 percent of the ohī'a survived the first fire in the lower elevation uluhe wet forest community, only 22 percent survived the second fire. Similarly, in the higher elevation tree fern community, survival of the ohī'a tree after the second fire dropped from 48 percent to 6 percent, and the native tree fern survival rate was reduced from 93 percent to 56 percent. Moreover, the understory was quickly overtaken by aggressive grass species. "In these highest elevation communities, we found an increase in invasive cover in the understory," Ainsworth says. This response causes concern that regeneration of the native ohī'a tree may be delayed or even prevented altogether by the invasion of non-native species in the understory.



Native Hap'u, Hawaiian tree fern (*Cibotium glaucum*) survival after fire in the understory of higher elevation rain forest. Credit: Alison Ainsworth.

## Creating a fire-tolerant landscape

Fire is not the only threat to the native plants and diversity of species in Hawai'i Volcanoes National Park. Damage also resulted from grazing and browsing by feral animals such as pigs and goats. "We lost native species even before the fires," says Loh. The removal of ungulates in the 1970s helped in the recovery of more common native species, but many were unable to recover without assistance. Included among the missing flora were species that had potential to survive wildfires.

Researchers have therefore been performing a kind of "triage" in an effort to identify and encourage the establishment of native species best adapted to fire. These are species that were part of the former community but had been reduced to very low numbers or extirpated by ungulates. Following fencing and removal of animals beginning in the 1970s, a subset of these missing native plants is now being reintroduced into fire-prone areas based on their ability to survive wildfire. Through wildfire effects studies conducted in the coastal plains and dry grasslands, and a series of research burns conducted between 1993 and 2000, the Park Service identified about 15 fire-tolerant, native species. "These are our building blocks to reestablish native species diversity in fire-prone communities," says Loh.

There are two different rehabilitation strategies. In the transitionally dry lower elevation savannah where sword fern and broomsedge were firmly entrenched, there was no regeneration of the ohia tree. The strategy here is not to attempt reforestation of this species, but to establish fire-tolerant native species and fire-proof the plant community.

In wet forests, the objective was to facilitate recovery of native species by selectively eradicating invasive species with mechanical treatment or using herbicides. The bottom line, says Loh, is that invasives throw a monkey wrench into the ecosystem after a fire, altering plant succession and fire cycles in areas that are not fire adapted. The work of Loh, Ainsworth, and colleagues has laid the groundwork for preservation of higher elevation habitats, where fires may become more common in the future.

## Management Implications

- In Hawai'i Volcanoes National Park, restoration of historic conditions has proven impractical in areas dominated by fire-adapted non-native vegetation.
- Where future fire is inevitable or highly likely, an alternative approach of re-introducing fire-tolerant native plants may allow for at least some native species to be retained in these altered ecosystems. Resource managers should prepare in advance by identifying the native plants most likely to thrive in the new fire regime.
- After a fire, managers need to quickly determine high priority areas for protection and strategically apply weed control.

## Further Information:

### Publications and Web Resources

- Ainsworth, Alison. 2007. Interactive influences of wildfire and nonnative species on plant community succession in Hawaii Volcanoes National Park. Masters' thesis submitted to Oregon State University. <http://ir.library.oregonstate.edu/dspace/bitstream/1957/4504/1/Ainsworth%20Thesis%20March%202007.pdf>
- McDaniel, Siera, Rhonda Loh, Susan Dale, Kimberly Smith, and Maya Vaidya. 2007. Rehabilitation of ohia swordfern (*Metrosideros polymorpha-Nephrolepis multiflora*) woodlands following the Kupukupu fire, Hawaii Volcanoes National Park. Technical Report of the Pacific Cooperative Studies Unit, University of Hawaii'i at Manoa.
- Tunison, J.T., J. Leialoha, R.K. Loh, L.W. Pratt, and P.K. Higashino. 1994. Fire effects in the coastal lowlands Hawaii Volcanoes National Park. The Pacific Cooperative Studies Unit (PCSU) and the Hawaii-Pacific Islands Cooperative Ecosystem Studies Unit (HPI-CESU). Technical Report 88. <http://www.botany.hawaii.edu/faculty/duffy/techr/088.pdf>
- Tunison, J.T., R.K. Loh, and J. Leialoha. 1995. Fire effects in the submontane seasonal zone Hawaii Volcanoes National Park. Cooperative National Park Resources Study Unit, Technical Report No. 97, Cooperative Agreement CA 8007-8002-9004. University of Hawaii Press, Honolulu. <http://www.botany.hawaii.edu/faculty/duffy/techr/097.pdf>

## Scientist Profiles

**Alison Ainsworth**, Natural Area Reserve Specialist with the Hawaii State Division of Forestry and Wildlife, received a Master's degree from Oregon State University in 2007 on fire effects following lava ignited wildfires. Prior to working for the state of Hawaii, Ainsworth was contracted by the National Park Service Inventory and Monitoring Program to write the vegetation monitoring protocol for the National Parks of the Pacific Islands.



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**The information in this Brief is written from JFSP Project Number 03-3-3-15, which is available at [www.firescience.gov](http://www.firescience.gov).**

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JFSP *Fire Science Brief*  
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January 2009

## ***Relationships of an Alien Plant, Fuel Dynamics, Fire Weather, and Unprecedented Wildfires in Hawaiian Rain Forests: Implications for Fire Management at Hawaii Volcanoes National Park***

Written By: Lara Durán

### **Purpose of this opinion piece**

*Manager's Viewpoint* is an opinion piece written by a fire or land manager based on information in a JFSP final report and other supporting documents. This is our way of helping managers interpret science findings. If readers have differing viewpoints, we encourage further dialogue through additional opinions. Please contact Tim Swedberg to submit input ([timothy\\_swedberg@nifc.blm.gov](mailto:timothy_swedberg@nifc.blm.gov)). Our intent is to start conversations about what works and what doesn't.

### **Problem**

Historically, through volcanic activity, lava-ignited wildland fires likely played a role in plant assemblage development and structure in the Hawaiian Islands. However, little is known about this fire's role. The introduction of non-native plants to the Hawaiian Islands is changing forest vegetation composition, structure, and therefore wildfire regimes. In many areas, non-native plants have completely replaced native plants. To gain the upper hand against non-native plants, information is needed about how fire affects native and non-native plant recovery, composition, and structure across elevation and vegetation assemblage gradients.

### **Application by Land Managers: Scope and Data**

This study contributes important fire ecology information specific to Hawaiian Volcanoes National Park (HVNP). Very little is known about the historic versus current fire ecology on the Hawaiian Islands, especially in the wet and mesic forests. In fact, it is quite difficult to get fire history data (such as fire return intervals) because, unlike mainland tree species, Hawaiian Islands inhabiting tree species do not record tree rings.

For instance, many of the national fire and fuels products, such as LANDFIRE and FRCC reference conditions, do not yet include the various vegetation assemblages found on the Hawaiian Islands ([Buck and Paysen 1984](#)). Yet, fires within this national park, like elsewhere in the northern hemisphere, are becoming more and more problematic for managers, with increased sizes and frequencies ([Tunison et al. 2001](#)). The complexity with invasive plants is exaggerated due to the presence of non-native grazers, such as feral pigs.

This project is the first attempt to analyze how fire interacts with native and non-native woody plants in wet forests at various altitudes, and within different size classes, species, and plant assemblages. Other studies within the park focused only on seasonally dry woodlands (Tunison et al. 2001). Earlier publications identified Rhonda K. Loh's study as one of the most important fire research studies needed in the Hawaiian Volcanoes National Park (Tunison et al. 2001).

### **Fuel Complex and Fire Regime Changes**

This study furthers our understanding of how different tree and shrub species re-colonize at a variety of elevations following fire. Cover type conversion in plant assemblages occurring at the lowest elevations where past repeated fires had happened facilitated the replacement of natives with non-natives. The huge increase of fuel loads from non-native ferns along with structural and vegetation composition changes from just one fire event will undoubtedly favor the non-natives and create that vicious fire regime-plant feedback loop—increasing fire size and frequency similar to what happens in mainland environments (Brooks et al. 2004, Tunison et al. 2001).

*This information can help managers make decisions about when or whether to use fire as a restoration or maintenance tool in vegetation management.*

This information can help managers make decisions about when or whether to use fire as a restoration or maintenance tool in vegetation management. However, the effects that non-native plants have on fuel complex and fire regimes complicate such management choices. Non-native grasses, herbs, vines, ferns, shrubs, and trees are believed to be responsible for changes from low-intensity, long-return interval fires to frequent, more intense fires (D'Antonio and Vitousek 1992, [D'Antonio et al. 2000](#), Brooks et al. 2004, Tunison et al. 2001).

This study also showed that repeat fires occurring in the presence of non-native plants can negatively impact species sensitive to fire. In areas where non-native plants have not assumed dominance, aggressive fire suppression that limits fire extent and non-native plant spread seems like the only necessary fire management choice.

### **Applying Allometric Models**

The development of allometric models for two dominant tree types will allow easier, faster, cheaper, and more accurate collection of dbh measurements alone compared to those requiring dbh and tree height. ("Allometric modeling" is the study of the change in proportion to various parts of an organism as a consequence of growth.) Using dbh alone, estimates of above-ground biomass, fire potential, and carbon sequestration can be made. These allometric models may spur the development of a FVS-FFE growth and yield model variant for the Hawaiian Islands. The investigators warn, however, that the models are less accurate at drier sites.

Measured fuel loadings and biomass using the site-specific allometric models developed in this study were higher than previously published in stereo photos ([Wright et al. 2002](#)). It is not clear from the publications if this fuel load increase is from encroachment of non-native plants, changes in decomposition rates, or some other factor. With improved fuel load and biomass estimates, fire managers may reconsider how their fire behavior predictions using the photo series compared with observed fire behavior under different weather conditions. Higher fuel loads may pose a higher safety hazard to fire fighters. Development of this improved model may alert fire managers to fuel type changes and potential fire behavior during incidents.



## Monitoring

Monitoring wildland fires will be necessary to provide managers with valuable information that connects site-specific fire weather and associated behavior with resulting fire effects and reproductive/survival strategies to non-native and native plant mortality.

This information can help managers and researchers find any critical thresholds that influence spread patterns or non-native plant dominance in previously native dominated sites. For instance, intensive fire monitoring may help answer one of the critical questions that emerged from this study: *Why did some of the study area within the fire perimeter remain unburned?*

Perhaps fire behavior analysts could help identify these reasons, especially if assigned to fire incidents. Without knowing the incident fire weather, it is hard to know how fire behavior influenced burn patterns. Nevertheless, it can be expected that future fires in the Hawaiian Volcanoes National Park are likely to have high levels of top kill, with an increase in native tree and plant loss, and an expansion of non-native plants.

## Outreach

This project is one example in which, out of necessity, aggressive education and outreach efforts combine with aggressive fire prevention and ecology activities. On-going efforts such as this web-based presentation and the Hawaiian Ecosystems at Risk project (HEAR) can be effective strategies. For, these activities increase public awareness, form strong partnerships between managers and researchers, and spur volunteer efforts that conserve native plants and reduce non-native plant dominance.

What may be missing on the Hawaiian Islands—as well as on the mainland—is a method for engaging those people outside the traditional circles that cross management and research pathways. For instance, we need to take advantage of opportunities to inform local communities about the role they play in the relationships between wildland fires, native and non-native plants, and biodiversity. This key audience includes: gardeners, farmers, and plant distributors. If we don't establish this communication, the introduction of non-native plants may continue to be a problem for land managers.

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The partnership formed through this project between the HVNP and academia—especially if its subsequent effort is large and well-focused—can make a strong impact. Partnerships are an excellent means of reaching a wider audience to raise awareness of impending and critical natural resource issues. Because many mainland residents are unaware of the land management challenges on the Hawaiian Islands, this is especially important. For instance, when budgets and personnel are tight, managers face difficult decisions about what parts of their programs to cut. Because it is difficult to measure their value and effectiveness, outreach and education programs are often the first to go.

Hopefully, future fire management and invasive plant management budgets for HVNP will reflect the increasing challenges associated with fire regime changes caused by invasive plants. To achieve this goal, a long-term commitment to funding is necessary. This can be achieved through constant efforts aimed at informing elected officials on the urgency, needs and values-at-risk.

## **Managing for Biodiversity**

The impact of non-natives has huge implications not only for fire managers, but this outcome also has even bigger implications for ecosystem diversity and resiliency. This equates to a loss of biodiversity, native vegetation, changes in soil carbon and nutrient cycling, carbon sequestration potentials, and associated changes in fauna assemblages. Like other tropical mesic and wet forests, Hawaiian forests are facing a deforestation of sorts from this vicious fire-invasive plant feedback loop. These changes in vegetation cover constitute a change in land color, which—as we see in mainland tropical deforestation—has drying effects on regional moisture regimes which could further hamper restoration (Hoffman and Jackson 2000, Nobre et al. 1991).

## **Restoration Options**

It seems critical that larger, more effective means of conserving native biodiversity must be undertaken in Hawaii. The biggest unanswered question, as posed by the investigators, concerns whether or not the survival, re-sprouting, and colonizing strategies of native plants will be enough to ensure their persistence when confronted with non-native plants?

To help address this question, future studies could look at competition between natives and non-natives at various time intervals and under varying conditions. Previous studies on herbicide use and prescribed fire might yield clues regarding how management actions might provide native plants with a competitive advantage over non-native plants (Castillo and McAdams 2006). Management can also benefit from knowing which native species respond most effectively to various actions and which are most effective for restoration and conservation. This includes having knowledge of native and non-native plant reproduction and re-colonization strategies for effects analysis in project planning.

In the meantime, managers can follow some of the options proposed by Brooks et al. (2004) in pilot projects. Despite the historical fire data gaps, the results from this study can strengthen management activities and decisions. For instance, managers can utilize this information to prioritize areas for restoration, focus on most effective areas for reintroduction of native plants, and identify vegetation communities at greatest risk and need for conservation.

Considering the sensitivity that native plants have to fire and the advantage it gives invasive plants, wildland fire use and application of prescribed fire sound risky and are therefore questionable as effective tools (Tunison et al. 2001, Brooks et al. 2004, DiTomaso et al. 2006, Castillo and McAdams 2006). Thus, active management, such as herbicide application, promises greater effectiveness than wildland fire use.

The sad possibility, however, is that managers may have to write-off some areas already dominated by non-native plants to limit the spread of invasive plants into highly valued or highly sensitive locations, to capitalize on the most effective and cost-efficient manner possible. This might include identifying locations that can serve as a future refuge for native plant diversity.

What's more, because the effects from fires last at least 10 years, the Hawaiian Island native plant conservation and non-native eradication efforts must be sustained. This furthers the urgency for managers and scientists to engage in long-term monitoring and research of non-native and native plant assemblages following fire and to include fire effects monitoring and fire behavior analysis as part of the monitoring program, just as with this study (Blossey 1999).

## References

- Blossey, Bernd. 1999. Before, during, and after: the need for long-term monitoring in invasive plant species management. In: *Biological Invasions* 1(2-3):
- Brooks, Matthew L., C.M. D'Antonio, D.M. Richardson, J.B. Grace, J.E. Keeley, J.M. DiTomaso, R.J. Hobbs, M. Pellant, and D. Pyke. 2004. Effects of invasive alien plants on fire regimes. In: *BioScience* 54(7): 677-688.
- Buck, Michael G. and T.E. Paysen. 1984. A system of vegetation classification applied to Hawaii. USDA Forest Service Pacific Southwest Forest and Range Experimental Station General Technical Report PSW-76.
- Castillo and McAdams. 2006. Effects of prescribed grazing and burning treatments on fire regimes in alien grass-dominated wildland-urban interface areas, Leeward Hawaii. Final Report to the Joint Fire Science Program Project No. 01-3-4-14.
- D'Antonio, Carla M., J.T. Tunison, and R.K. Loh. 2000. Variation in the impact of exotic grasses on native plant composition in relation to fire across an elevation gradient in Hawaii. In: *Austral Ecology* 25: 507-522.
- D'Antonio, Carla M. and P.M. Vitousek. 1992. Biological invasions by exotic grasses, the grass/fire cycle and global change. In: *Annual Review of Ecology and Systematics* 23: 63-87.
- DiTomaso, Joseph M., M.L. Brooks, E.B. Allen, R. Minnich, P.M. Rice, and G.B. Kyser. 2006. Control of invasive weeds with prescribed burning. In: *Weed Technology* 20: 535-548.
- Hoffman, William A., and R.B. Jackson. 2000. Vegetation-climate feedbacks in the conversion of tropical savanna to grassland. In: *Journal of Climate* 13(9): 1593-1602.
- Tunison, J. Timothy. 1992. Alien plant control strategies in Hawaii Volcanoes National Park. In: C.P. Stone, C.W. Smith, and J.T. Tunison (eds.) *Alien Plant Invasions in Native Ecosystems of Hawaii: Management and Research*. Cooperative National Park Resources Studies Unit, University of Hawaii, Manoa.
- Tunison, J.T., C.M. D'Antonio, and R.K. Loh. 2001. Fire and invasive plants in Hawai'i Volcanoes National Park. In: K.E.M. Galley and T.P. Wilson (eds.). *Proceedings of the Invasive Species Workshop: the Role of Fire in the Control and Spread of Invasive Species*. Fire Conference 2000: the First National Congress on Fire Ecology, Prevention, and Management. Miscellaneous Publication No. 11, Tall Timbers Research Station, Tallahassee, FL.
- Tunison, J. Timothy, C.W. Smith, and C.P. Stone. 1992. Alien plant management in Hawaii: Conclusions. In: C.P. Stone, C.W. Smith, and J.T. Tunison (eds.) *Alien Plant Invasions in Native Ecosystems of Hawaii: Management and Research*. Cooperative National Park Resources Studies Unit, University of Hawaii, Manoa.
- Wright, Clinton S., R.D. Ottmar, R.E. Vihnanek, D.R. Weise. 2002. Stereo photo series for quantifying natural fuels: grassland, shrubland, woodland, and forest types in Hawaii. Gen. Tech. Rep. PNW-GTR-545. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 91 p.

## Manager Profile

Lara Durán is a Fire Planner for the Sawtooth National Forest in Idaho. Her previous positions included Fuels Specialist, Fire Prevention, and Wildlife Technician for the U.S. Forest Service in Colorado. Lara contributed to the JFSP Risk Roundtable, Manager's Reviews, and participated in the national pilot program Integrated Landscape Design to Maximize Fuel Reduction Effectiveness.

She earned a BA in Ecology from the University of Colorado at Boulder where she earned a National Science Foundation grant for undergraduate research in alpine plant development. She was a Wildlife and Plant Ecology Research Assistant at the University of Colorado, contributing to long-term studies on ponderosa pine, Abert squirrels, dwarf mistletoe, elk, American marten, and yucca plants. Since then, she's completed graduate courses in wildlife and plant ecology, law, and administration. She is interested in disturbance ecology and the effects to wildlife.



*The information for this Manager's Viewpoint is based on JFSP Project 03-3-3-15, Relationships of an Alien Plant, Fuel Dynamics, Fire Weather, and Unprecedented Wildfires in Hawaiian Rain Forests: Implications for Fire Management at Hawaii Volcanoes National Park; Principal Investigator was Rhonda K. Loh.*