

# Hō'ike o Haleakalā

*Haleakalā revealed: an opening to view our past and embrace our future  
Reveal yourself, summit to sea*

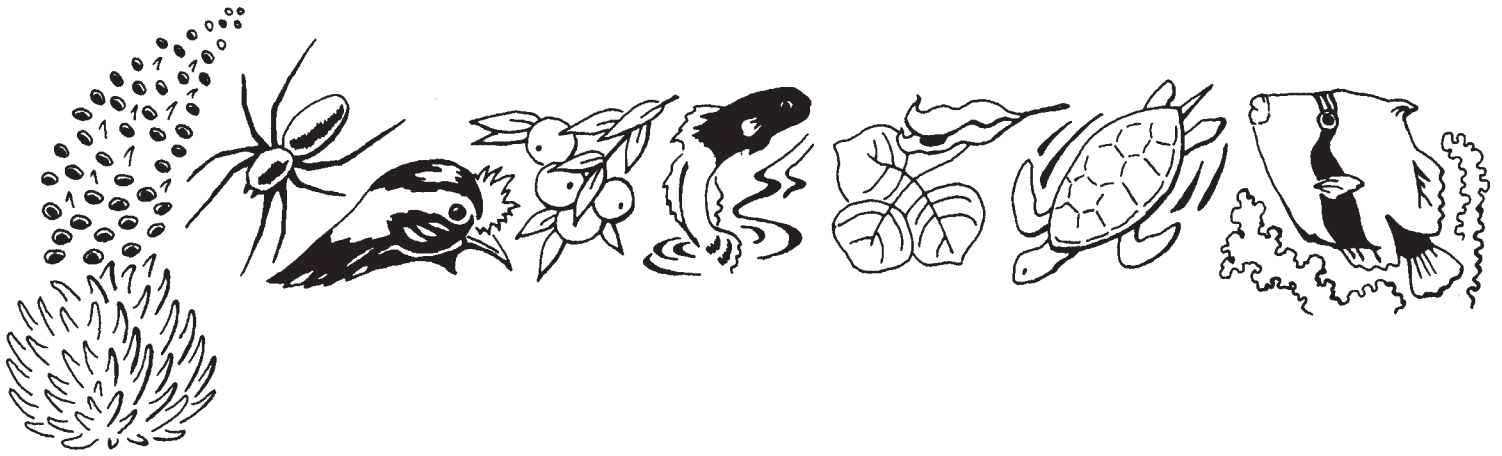


## A Multidisciplinary, Science-Based Environmental Education Curriculum for High Schools



Produced by  
Hawai'i Natural History Association  
*Nā Kumu o Haleakalā*  
Haleakalā National Park  
The Nature Conservancy

*Major funding provided by the Strong Foundation  
Additional support provided by the Alexander & Baldwin Foundation,  
Atherton Family Foundation, Fred Baldwin Memorial Foundation, and Cooke Foundation, Limited*



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# Foreword



*Nā Kumu o Haleakalā* is a partnership on the island of Maui, Hawai‘i, comprised of teachers from public and private high schools, members of interested community organizations, and staff from the Hawai‘i Natural History Association, Haleakalā National Park, and The Nature Conservancy. The *Nā Kumu* partnership has worked with a highly qualified curriculum writing and development team to produce the beginnings of a comprehensive environmental education curriculum, *Hō‘ike o Haleakalā*, specific to Maui to promote understanding of island ecosystems, a feeling of shared ownership, and a commitment to active stewardship. The target group is primarily high school level, though testing will occur in the local community college and in intermediate schools, as well. The effort was initiated by the National Park Service and local teachers in 1996, and gradually gathered momentum until 1999, by which time sufficient funding had been raised from several private sources to move ahead. The partnership has recently completed ecosystem-based modules for aeolian, rainforest, and the coastal/marine zones of Haleakalā. Future plans call for these to be followed by modules on dryland forest, the subalpine zone, watersheds, and a culminating module on alien species.

Although not entirely conceived as such originally and having much broader educational objectives, *Hō‘ike o Haleakalā* can be thought of as an innovative effort at educating local students to understand the overwhelming effects of invasive alien species (IAS) on biodiversity, agriculture, health, economy, and quality-of-life of an oceanic island ecosystem, and to obtain long-term public support of and participation in such efforts. Each ecosystem-based module has one or more units on the effects and/or future threats of alien species. Haleakalā National Park is the most biologically intact summit-to-the-sea reserve in the Hawaiian Islands and among the most important reserve sites in the United States for conservation of biodiversity. However, the park’s future depends on resource managers’ success in combatting invaders already present and on efforts to prevent additional IAS from establishing on the island of Maui. Since oceanic islands are particularly vulnerable to biological invasions, IAS threats to Hawai‘i and to Haleakalā National Park on Maui are an order of magnitude greater than threats to most other U.S. national parks. The red imported fire ant and Asian longhorn beetle are not yet established in Hawai‘i, but both have been recently intercepted in quarantine. Unless major action is taken – a circumstance which will require solid public support — invasions can be expected to erode the biological integrity of oceanic island ecosystems, eventually even the last strongholds of the endemic island biota.

Lloyd Loope  
Research Biologist, U.S. Geological Survey,  
Biological Resources Division, Haleakalā National Park



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# Acknowledgements

*Hō‘ike o Haleakalā* was created with the cooperation, support, and advice of numerous individuals from Maui and beyond. Many of them are listed below. Thanks to everyone who helped make this vision a reality.

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Hawai‘i Wildlife

The Nature Conservancy

University of Hawai‘i

Hawai‘i Natural History Association

Hawai‘i Department of Land and Natural Resources, Division of Forestry and Wildlife

University of Hawai‘i - Manoa

University of Hawai‘i - Manoa

University of Hawai‘i - Hilo

University of Hawai‘i - Hilo

University of Hawai‘i - Manoa

Hawai‘i Department of Land and Natural Resources, Division of Forestry and Wildlife

Kai Malino Wellness Center

Kīhei Canoe Club

Polynesian Voyaging Society

Haleakalā National Park

Maui Invasive Species Committee

U.S. Geological Survey, Biological Resources Division, Haleakalā National Park

Hawai‘i Sea Grant

Keālia Pond National Wildlife Refuge

Moanalua Garden Foundation

Haleakalā National Park

U.S. Geological Survey, Hawai‘i Volcanoes Observatory

Department of Land and Natural Resources, Division of Aquatic Resources

Hawai‘i Natural History Association

Kaho‘olawe Island Reserve Commission

U.S. Geological Survey, Biological Resources Division, Haleakalā National Park



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# Introduction

## *Hō'ike o Haleakalā*

*Haleakalā revealed: an opening to view our past and embrace our future*

*Reveal yourself, summit to sea*

## Project Background and Purpose

There are some 6,000 high school students in Maui County. Many of them have never seen a native bird or experienced a native Hawaiian forest. Many of them have no reference point, no experience to know whether the birds they see or the forests they visit are native to the Hawaiian Islands.

This lack of knowledge and experience may not be surprising. Roughly 75 percent of the original Hawaiian forest is gone and the remnants of native forest that remain tend to be difficult to access. Forests, scrublands, and coastal areas dominated by nonnative species are all many Hawaiian residents know. Over 100,000 species of plants alone have been introduced to the Hawaiian Islands since the arrival of the first Polynesians, and many of these now predominate in areas once covered by native vegetation. Furthermore, while the Hawaiian Islands make up well under one percent of the total land mass of the United States, 75 percent of the country's recorded plant and bird extinctions are of Hawaiian species.

Intimately tied to the land, traditional Hawaiian culture, values, and ways of life have declined along with the native plants and animals. Today's residents have little connection to the land—and little connection with the achievements and customs of the ancient Hawaiians. Like many native Hawaiian birds, insects, and plants, Hawaiian cultural values sometimes seemed threatened by extinction—through lack of awareness and understanding.

*Hō'ike o Haleakalā* aims to help sustain the native Hawaiian landscape and culture by helping students establish and deepen connections to the land and the culture it supports. Project goals are to enable high school students in Maui County—and elsewhere throughout the Hawaiian Islands and beyond—to:

- Gain a greater understanding of island ecosystems;
- Develop an awareness of relationships between people and the environment;
- Build observation, critical-thinking, and decision-making skills;
- Feel a sense of inspiration for and shared ownership of natural areas; and
- <sup>a</sup> Become informed decision-makers active in the stewardship of their island home.

## From Vision to Reality

Since 1996, educators from public and private Maui high schools, Haleakalā National Park, Hawai'i Natural History Association, The Nature Conservancy, and members of several community groups have been sharing ideas for improving natural history education in Maui County's secondary schools. Out of these discussions came the idea to, in effect, bring the mountain and its fascinating array of natural systems to the classroom.

*Hō'ike o Haleakalā* is a fulfillment of that vision. This classroom-based curriculum provides educators with background information, resources, teaching suggestions, and activities for teaching science



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and other academic skills in the context of topics and issues relevant to Haleakalā, Maui, and the other Hawaiian Islands.

*Hō‘ike o Haleakalā* is a multi-disciplinary, science-based environmental education curriculum that supports State of Hawai‘i high school educational standards, particularly in the science disciplines. Each activity is correlated to state science standards, offering educators a way to fulfill educational requirements using local ecosystems and issues as a context. These materials help you bring science home for your students while fostering a strong science background and critical-thinking skills.

Today’s young people have the future of Hawai‘i in their hands. They need to know the value of our natural and cultural environment before they can be active stewards. *Hō‘ike o Haleakalā* is a celebration of this unique heritage, an exploration of the modern landscape, and an invitation to stewardship.





# How to Use This Curriculum

*Hō'ike o Haleakalā* can be used to structure a semester-long (or longer!) course focusing on native ecosystems and natural resource management issues. Alternatively, the modules, units, and activities in this curriculum may be taught separately. Activities may be infused into standard science classes and some are also suited to use in language arts, mathematics, Hawaiian studies, or social studies classes.

## Curriculum Components

The *Hō'ike o Haleakalā* curriculum is divided into four modules, each of which covers a discrete ecosystem on Haleakalā. The modules—and the icons used to represent the ecosystems—are:



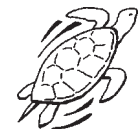
### Alpine/Aeolian

The wolf spider (*Lycosa hawaiiensis*) is an endemic species found only near the summit of Haleakalā.



### Rain Forest

The 'ākohekohe or crested honeycreeper (*Palmeria dolei*) is an endemic forest bird once found on both Maui and Moloka'i but now found only on East Maui. It is endangered.



### Coastal

The honu or green sea turtle (*Chelonia mydas*) is an indigenous reptile that spends much of the year in the coastal waters around the main Hawaiian Islands, migrating up to 800 miles to the Northwestern Hawaiian Islands for summer nesting season. The honu is listed as a threatened species.



### Marine

The humuhumunukunukuapua'a or Picasso triggerfish (*Rhinecanthus rectangulus*), a common fish on shallow reef flats, was voted the Hawai'i State Fish in 1984. Its Hawaiian name means “nose like a pig.”

You'll find the icon for each module in the header of each page of that module.



All of the pages associated with the curriculum as a whole (such as this introduction or the glossary) are indicated by an icon depicting 'āhinahina, the Haleakalā silversword (*Argyroxiphium sandwicense* subsp. *macrocephalum*). The 'āhinahina is a threatened endemic plant found only on the upper slopes of Haleakalā, and associated around the world with this place.

Each module is divided into five units, each comprised of two to four distinct activities. Each unit and many of the activities may be used separately to supplement your existing lesson plans. Or teach one or more units or an entire module in sequence for a more complete learning experience.



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## Module Format

Each module consists of five units. Together these units comprise a thorough exploration of the ecosystem. Individual units in each module address key aspects of the ecosystem’s physical characteristics, plant and animal species and relationships, and related management issues.

## Module Introduction

- **Ecosystem Connections**—Two pages that give a visual sense of the ecosystem and, through quotations and Hawaiian chant, illustrate its importance to humans  
*Photocopy these pages for students or make acetates of them to introduce the ecosystem before beginning a module or unit.*
- **Ecosystem Summary**—An overview of ecosystem characteristics and status
- **Traditional Hawaiian Significance**—A brief account of the Hawaiian cultural significance of the life zone
- **Journal Ideas**—Suggested topics for journal entries or writing assignments to get students thinking about the ecosystem
- **To Get a Feel for . . .** —A brief activity to introduce students to the life zone
- **Units at a Glance**—An overview of the five units that comprise each module, including the topics covered, the importance of the unit, and constituent activities
- **Optional Field Activities**—A description of field trips, service projects, and other field learning opportunities related to the ecosystem

## Five Units

Each unit includes:

- **Introductory Information**—Includes a brief unit overview (read aloud to students before beginning a unit or an activity), length of the unit, and unit focus questions.
- **Unit at a Glance**—Activity-by-activity summary including:
  - Description
  - Length
  - Prerequisite Activity (if any)
  - Objectives
  - DOE Science Standards and Benchmarks met by the activity.
- **Enrichment Ideas**  
*Use these ideas to build on the activities in each unit. These include suggestions for independent projects, additional research, extending the activities, and putting knowledge into action.*
- **Resources for Further Reading and Research**  
*These resources may be equally useful to both instructors and students.*



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- **Activity Instructions and Materials**

- Materials & Setup—Materials and equipment needed for the activity
- Instructions—Step-by-step guidance for conducting the activity
- Journal Ideas—Topics for journal entries or stand-alone writing assignments

*These written assignments are integral parts of each activity, often helping students explore their personal connections with the subject matter and cement key learning objectives. Selecting from among these—or creating your own topics—also help you focus on the standards and objectives that are most important to you. Some of the journal ideas are appropriate for using before and after a unit to give students an opportunity to reflect on what they learned.*

*Have students keep a journal if you are teaching the entire curriculum or a substantial piece of it. Collect journals periodically to assess student learning and reflection. If you are teaching a single activity or unit, you may choose to use the journal ideas as writing assignments instead of topics for journal entries.*

- Assessment Tools—Ideas to help you assess student performance
- Teacher Background—Additional information, intricate activity instructions, and other support
- Masters for Overhead Acetate Transparencies, Game Cards, and Other Instructional Materials—These masters may be easily identified by looking for the descriptive label in the page header (e.g., “Game Card Master”).
- Masters for Student Pages—These activity, data, or reading sheets to duplicate for student use are easily identified by a shaded bar running the length of the page in the right-hand margin containing the label “Student Page.”

## Vocabulary Words

Technical terms and those that might be difficult for students to understand are explained or defined in the text of student pages and enclosed in quotation marks the first time they are used. These words are also included in the glossary that accompanies this curriculum at the beginning of each module. This glossary is designed as an easy reference for instructors, but it may be photocopied for student use as well. Most glossary words are followed by a notation indicating the unit(s) in which the terms are used. Those that include no unit number notation are words common to most of the units such as “ecosystem.”

## Additional Resources

A complement of additional resources such as reports, game boards, reference books, and video tapes accompanies this curriculum. See notations within individual activities that indicate these materials. Where possible, these materials are included in a pocket that accompanies the relevant unit. Resources that are too large to fit in such a pocket are included separately.



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## Beyond the Classroom & Beyond This Curriculum

With the help of *Hō'ike o Haleakalā*, you can bring Haleakalā into your classroom, helping to make the unique natural history and ecology of the island a part of your students' lives. The activities that are included in *Hō'ike o Haleakalā* are an excellent accompaniment to field trips, service projects, and other activities that take students outside the classroom to experience the unique natural environment they are studying. Each module contains suggestions and contact information for field-based learning.

Whether you select a single activity or teach an entire course using *Hō'ike o Haleakalā*, we thank you for joining us in spreading the word about the unique and imperiled environment of our island home.



# Alpine/Aeolian Module



You are here.

## ● ● ● What Does the Alpine/Aeolian Zone Mean to You?

*These reflections are offered by individuals involved in studying and protecting the native ecosystems of Haleakalā.*

House of the sun, house of the snow  
Silerswords

—Kim Martz and Forest Starr

From here, one can only look up to the heavens, to the edge of our existence. Every day, for those who inhabit this ecosystem, the edge of life and death is as razor-thin as the distant horizon. Here, two worlds can collide: The warmth of the sun and the fire of the Earth!

—Eric Andersen

Sacred elder, the *piko* of East Maui  
The wind blowing my hair

—Kalei Tsuha

Looking up at Red Hill or gazing down into that vast expanse of the “crater,” it’s easy to get the impression that the place is lifeless. There is more than meets the eye in this great depression of Haleakalā. The more you look, the more you see.

—Betsy Gagné



*Photo: Sharon Ringsven*

### ***Mele Ho'āla***

*E ala e!  
Ka lā i ka hikina  
I ka moana  
Ka moana hohonu  
Pi'i i ka lewa  
Ka lewa nu'u  
I ka hikina, aia ka lā  
E ala e!*

Wake up!  
The sun is in the east  
In the ocean  
Down deep  
It climbs upward  
To the spacious realm above  
Eastward is the sun  
Wake up!

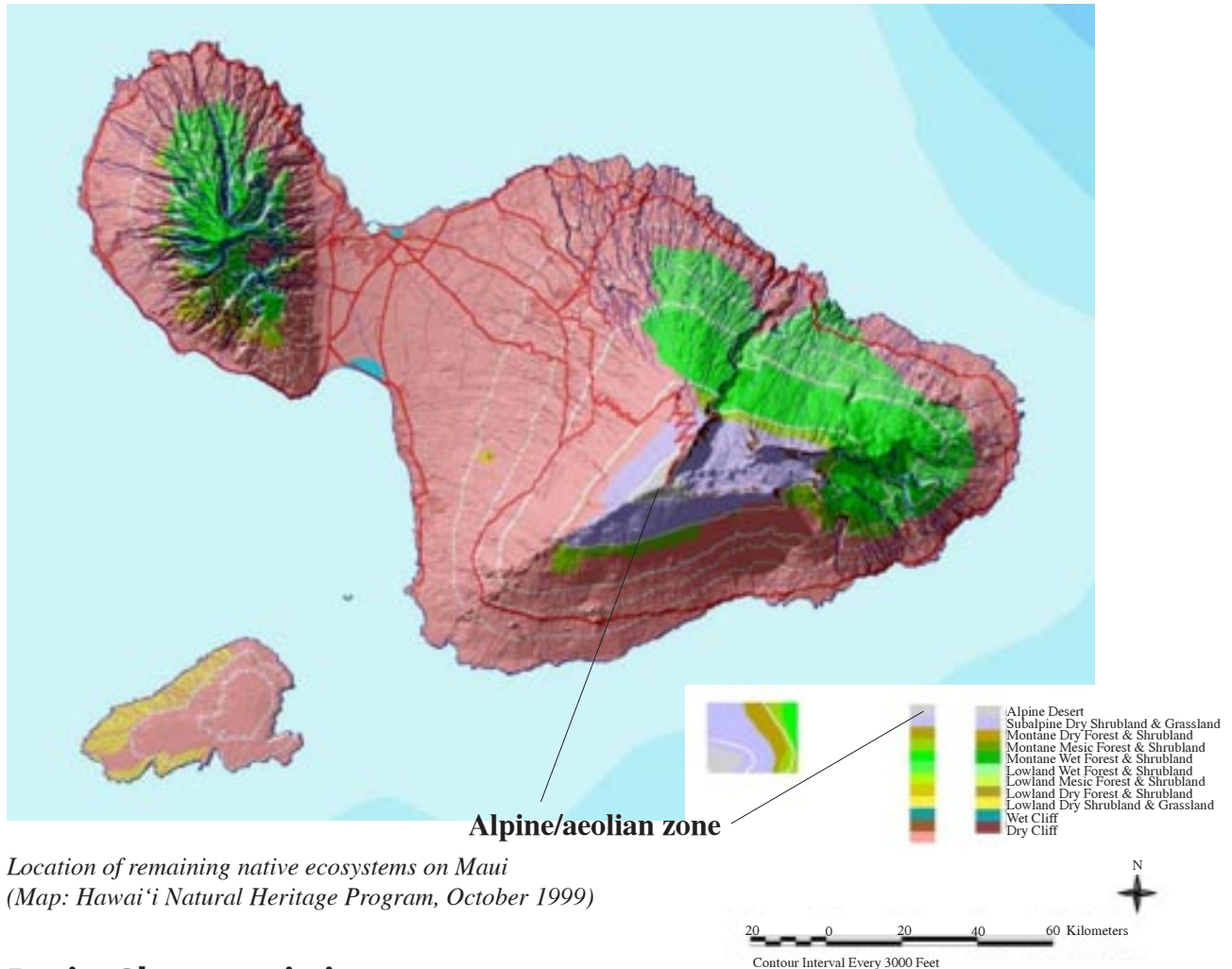
*Pua Kanahale  
1992*



## ● ● ● Ecosystem Summary

### Where on Haleakalā?

The alpine/aeolian ecosystem is located above 2300 meters (7544 feet) elevation in the cinder-dominated summit basin; above 2600 meters (8528 feet) on the older western, outer slopes of the summit basin. It extends to the summit at 3056 meters (10,023 feet).



## Basic Characteristics

This high-altitude region is characterized by sparse vegetation (generally 0-5% cover), scarce food sources for insects and other animals, generally dry conditions, and an extreme climate with widely varying daily temperatures and intense solar radiation.

## Did You Know?

“Aeolian” is a term first used in 1963 by L.W. Swan to describe communities of insects that survive on high-elevation landscapes of snowfields and barren rock. These systems, where little vegetation grows, are fueled primarily by organic matter blown in on the winds. These systems are appropriately named after Aeolus, Greek god of the wind.

On Haleakalā, a unique collection of arthropods (the family that includes spiders, insects, and centipedes) has evolved to take advantage of the insect life and plant matter that is blown in by the upslope winds.



## Status and Threats

The alpine/aeolian is perhaps the most intact ecosystem type on Maui. Most of its historic extent has been maintained through more than 1500 years of human contact. Until recently, this environment has been little influenced by nonnative species, and the native insect fauna is still nearly intact.

For many years, vegetation in this zone was damaged by feral goats. Much vegetation has recovered following the erection of protective fencing and the removal of the goats.

Ants, rodents, and nonnative parasitic insects threaten native insects and the plants with which they coexist. Careful management of the increasingly popular Haleakalā National Park (which encompasses 50-60 percent of the alpine/aeolian ecosystem on Maui) is necessary to protect this nearly intact system, since human activities tend to expand the range of nonnative species. Activities linked with observatories and communications structures in the summit area must also be managed carefully.

## ● ● ● Traditional Hawaiian Significance

Keen observers of the islands' natural communities, early Hawaiians identified twelve life zones that stretched from *makai* to *mauka*. Haleakalā and the surrounding ocean encompass all of these zones, many of which have been dramatically changed by human use. At the top of Haleakalā, however, are two zones where the natural communities are still largely intact—the *kuahiwi* (backbone) and *kuamauna* (back mountain). These zones comprise what we know as the alpine/aeolian ecosystem.

In the traditional system of dividing the Hawaiian Islands into political regions, the *ahupua'a* was the most important land division. *Ahupua'a* usually extended from these upper reaches of the mountains to the outer edge of the reef in the ocean, cutting through all of the major environmental zones along the way. Each *ahupua'a* encompassed most of the resources Hawaiians required for survival, from fresh water to wild and cultivated plants, to land and sea creatures. Because of their dependence on the land's resources, the Hawaiians developed a complex system of resource management and conservation that could sustain those resources over time. This system was tied intimately to the religious and cultural beliefs of the Hawaiian people.

In Hawaiian tradition, the upper reaches of the mountain are the sacred House of the Sun (a literal meaning of Haleakalā), where every day begins. Today, people still visit the summit just to see the moment when the sun rises above the distant horizon. This is the place where the demigod Māui snared the sun to slow its passage across the sky and make it easier for his mother to dry her *kapa* cloth.

At the height of Hawaiian society, this gathering place of the gods was visited by few people. *Kāhuna*, Hawaiian spiritual leaders and elders, went there for meditation and to receive spiritual information. The *kilo hōkū* (astronomers) brought young men training to be navigators up the mountain to teach them about the sky and the stars. Important people were buried up there, and there is a place where people buried the *piko* (umbilical cords) of their babies.

Hawaiians constructed shelters in the summit area, but no one lived there. Workers came to quarry rocks for making adzes and other tools. Hunters came to hunt 'ua'u (petrels) for food. Travelers sometimes passed through while crossing from one side of the island to the other and perhaps stopped to collect a gift such as a bird feather before continuing on.

Before going to the summit of Haleakalā, Hawaiians had to ask permission from human authorities and from the gods. Among those who were given permission to enter this sacred place were men who quarried basalt rock for making adzes and other tools. Today, many Hawaiians continue to pray for permission before they go to the summit. This area is no less sacred today than it was in times past.





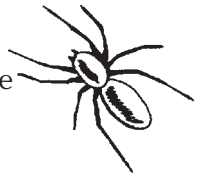
### ● ● ● Journal Ideas

Use some or all of the following topics for student journal entries:

- Listen to the chant as it is read in Hawaiian. How would you describe the feeling of the chant? What did it make you think about?
- Listen to the English translation of the chant. Do you have different thoughts and feelings now that you know what this chant means in English?
- Have you ever been to the top of Haleakalā? What are your impressions of this area?
- If you haven't been to the summit, whom do you know who has been? What do you think that person saw and felt like up at the top of Haleakalā?

### ● ● ● To Get a Feel for the Alpine/Aeolian Zone

The Living in the Extremes slide show (Unit 3, Activity #1 “Alpine/Aeolian Challenges and Adaptations”) helps students visualize the alpine/aeolian ecosystem. You may use it as an introduction for any unit or activity.



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## ● ● ● Alpine/Aeolian Units at a Glance

### Unit 1

#### Learning from the Mountain

##### Subject

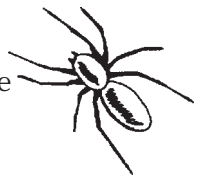
Geology of the summit area and how people study it

##### Importance

The geological features of the summit area help shape the conditions under which life survives in the alpine/aeolian zone.

##### Activities in This Unit

- **Haleakalā Past and Present**  
Students study the origin of Hawaiian volcanoes, including Haleakalā, and relate the history of these volcanoes to present conditions in the alpine/aeolian ecosystem.
- **Haleakalā Detective Work**  
Students learn how geologists apply the scientific method to posing and answering questions about the past and future of Haleakalā and describe examples of hypothesis creation and testing.
- **The Dating Game**  
Students play a game in which they demonstrate their knowledge of the geology of Haleakalā and proper visitor behavior in the alpine/aeolian ecosystem.



## Unit 2

# Summer Every Day and Winter Every Night: Climate and Conditions in the Alpine/Aeolian Zone

## Subject

Climate of the summit area

## Importance

Climate is a key factor in shaping the environmental conditions to which life in the alpine/aeolian zone is adapted.

## Activities in This Unit

- **What's the Temperature at the Summit?**  
Students predict the temperature at the summit of Haleakalā based on the current temperature at their school, and discuss possible explanations for differences between their calculations and the actual temperature.
- ***Mauna Lei* Mystery**  
By investigating and learning about the climate conditions that form the *mauna lei*, or the layer of clouds that often rings Haleakalā, students learn about the environmental conditions of the alpine/aeolian ecosystem.
- **Summer Every Day and Winter Every Night?**  
Students analyze temperature information available on the Internet to draw conclusions about the applicability of the statement “summer every day and winter every night” to the alpine/aeolian ecosystem.



## Unit 3

### Life in the *Kuahiwi* and *Kuamauna* Zones

#### Subject

Native and introduced species, relationships, and adaptations

#### Importance

The small number of plant and insect species native to the alpine/aeolian zone have evolved together into natural communities that are among the least altered of any on Haleakalā. These specialized relationships are threatened by a growing number of introduced species.

#### Activities in This Unit

- **Alpine/Aeolian Challenges and Adaptations**  
Students learn about plant and animal adaptations to the harsh alpine/aeolian environment through a slide show and a group activity.
- **Holding On to Water Lab**  
Students perform an experiment in which they replicate alpine/aeolian environmental conditions and devise structural features that prevent desiccation.
- **Adaptations Game Show**  
Students play a game to solidify and demonstrate their knowledge of environmental conditions in the alpine/aeolian ecosystem and how plant and animal life is adapted to these conditions.
- **Web of Life Game**  
Students play a game to explore the similarities and relationships among species in the alpine/aeolian ecosystem.



## Unit 4

### Good Critters, Bad Critters

#### Subject

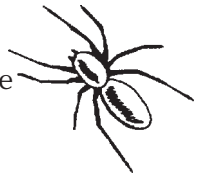
Insect management in the alpine/aeolian ecosystem

#### Importance

Relationships among insects and plants in the alpine/aeolian zone are only partially understood, but native insect pollinators are known to play a crucial role in plant reproduction. Invasions of alien insects threaten native insect populations and the native plants that depend upon them for pollination.

#### Activities in This Unit

- **To Spray or Not to Spray**  
Students propose a response to a management dilemma that arose in 1968, involving protecting *‘āhinahina*, the Haleakalā silversword, from insect damage.
- **Ant Alert: How Does Invasion Threaten Natives?**  
Students compare the invasive Argentine ant to other ant species to understand why the Argentine ant is such a potential threat to the alpine/aeolian ecosystem on Haleakalā. In teams, they teach each other about the threat Argentine ants pose.
- **Controlling the Argentine Ant**  
Students propose ideas for controlling the spread of Argentine ants in Haleakalā National Park, compare their ideas to what’s already being done, and evaluate the efficacy of current control efforts.



## Unit 5

### Observatories, Transmitters, & Sacred Places: How Should the Summit Area Be Used?

#### Subject

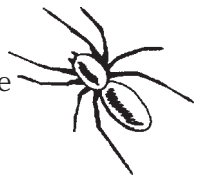
A contemporary issue revolving around the significance and use of the summit area

#### Importance

People have many different perspectives about the importance of the summit area and which human uses are appropriate there. These perspectives and how they are expressed influence how the top of Haleakalā is used.

#### Activities in This Unit

- **Exploring the Importance of the Summit**  
Students explore the significance of the summit area of Haleakalā from as many perspectives as they can think of, including its traditional Hawaiian importance and its suitability as a place for observatories.
- **In-Class Public Forum**  
Students use existing points of view to develop testimony for an in-class “public forum” on an issue about the appropriate use of the summit area. Students also articulate their own perspectives on this issue.
- **What Goes On at the Observatories?**  
Students perform Internet research to learn about the work that is being done in the observatories on Haleakalā.



## ● ● ● Optional Field Activities

Getting students out in the field puts them in direct contact with the ecosystem and gives them a context for learning. These are excellent supplements to the classroom-based activities of the alpine/aeolian module, giving students the excitement and challenge of hands-on experiences. Here is a listing of resources for field trips and other extensions.

### Field Trips

Haleakalā National Park

Sliding Sands Trail Hike

#### Description

Ranger-led or unguided hike

Students hike down the Sliding Sands Trail part-way into the summit basin. Students will see the sparse vegetation of the alpine/aeolian zone, the colorful cinder cones of the summit basin, and depending on the time of day, the cloud layers building up around the mountain. Wind up with a picnic lunch at Hosmer Grove.

You may combine this hike with a trip to the Haleakalā Visitor Center.

#### Field Trip Time

Two hours to a half day (not including travel)

#### Cautions

- At high elevations, the weather can change rapidly and may range in extremes from hot and sunny to cold, windy, and rainy.
- High elevations may complicate health conditions such as asthma.
- The Sliding Sands Trail is steep in spots with shifting footing, which can be strenuous at the high elevation. Allow approximately twice as long to hike back up as it takes to hike down.

#### What to Bring

- Dress in layers with warm clothes to protect against the wind and cold weather at the summit.
- Sunscreen and a hat
- Sturdy walking shoes (not slippers)
- Water and a lunch or snacks
- Optional: Camera

#### Group Size Limits

Ranger-led hikes, maximum group size of 40 people

Unguided hikes, maximum group size of 12 people including students and teacher

#### Contact

Call the Environmental Education Coordinator at 572-4453 to arrange ranger-led hikes and programs. Allow two to three months advance notice to arrange a ranger-led hike.

**Fees**

No fees for a ranger-led hike

For unguided hikes, apply two to three weeks in advance for a fee waiver from the Fee Supervisor at 572-4441.

**Getting There**

Begins in the summit area of Haleakalā National Park, about a two hour drive from Wailuku.

## Haleakalā Visitor Center

**Description**

Unguided field trip

Take students to the Haleakalā Visitor Center near the summit of Haleakalā, and to the summit, where interpretive exhibits explain aspects of the geology and ecology of the alpine/aeolian zone. Students will see the sparse vegetation of the alpine/aeolian zone, the colorful cinder cones of the summit basin, and depending on the time of day, the cloud layers building up around the mountain. Wrap up with a picnic lunch at Hosmer Grove.

**Field Trip Time**

Two to four hours (not including travel)

**Cautions**

- At high elevations, the weather can change rapidly and may range in extremes from hot and sunny to cold, windy, and rainy.
- High elevations may complicate health conditions such as asthma.

**What to Bring**

- Dress in layers with warm clothes to protect against the wind and cold weather at the summit.
- Sunscreen and/or a hat
- Water and a lunch or snacks

**Group Size Limits**

None

**Contact**

Call the Environmental Education Coordinator at 572-4453 to discuss options for ranger-led programs or an introductory talk.

**Fees**

No fees for a ranger-led program

For unguided field trips, apply two to three weeks in advance for a fee waiver from the Fee Supervisor at 572-4441.





## Getting There

This field trip begins in the summit area of Haleakalā National Park, about a two-hour drive from Wailuku. A full-size bus must stop at the Haleakalā Visitor Center and cannot go to the summit. Vans and cars are allowed in the summit parking lot.

## Skyline Trail

### Description

Unguided hike

Hike with students along the upper portion of the Skyline Trail past the Haleakalā Observatories and the proposed site of the coordinated broadcast facility. Students will see the sparse vegetation of the alpine/aeolian zone, the cinder cones of the Southwest Rift Zone (along which the most recent eruptions have occurred), and a landscape covered with red, gray, orange, and pink volcanic cinders interspersed with red and black lava bombs.

You may combine this hike with a trip to the Haleakalā Visitor Center.

### Field Trip Time

Depending upon the length of your hike along the Skyline Trail, allow three to four hours for this hike and lunch (not including travel time).

### Cautions

- At high elevations, the weather can change rapidly and may range in extremes from hot and sunny to cold, windy, and rainy.
- High elevations may complicate health conditions such as asthma.
- At high elevations, allow approximately twice as long to hike back up as it takes to hike down.
- Take care to stay on the main trail, avoiding the turnoffs to the scientific and broadcast facilities in the area. Staying on the trail is also important because exploring lava fields can be dangerous and because the few plants and insects that inhabit this high country are vulnerable to being crushed by hikers straying from the trail.

### What to Bring

- Dress in layers with warm clothes to protect against the wind and cold weather at the summit.
- Sturdy walking shoes (not slippers)
- Sunscreen and/or a hat
- Water and a lunch or snacks

### Group Size Limits

None for noncommercial groups

### Contact

You should inform the Department of Land and Natural Resources, Division of Forestry and Wildlife office of your field trip plans so field staff are aware that you are a school group and not a commercial group. The number is 984-8100.



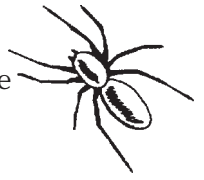
### Getting There

The trail begins in the summit area of Haleakalā National Park, about a two-hour drive from Wailuku. Have the bus drop your group at the turnoff for Haleakalā Observatories and follow the road to the trailhead. Or park smaller vehicles at the summit and carefully walk back down the road to the turnoff. The Skyline Trail branches off from this road to the left (*makai*), a little past the National Park boundary sign.

## Connecting Your Field Trip to the Alpine/Aeolian Module

Here are some ideas for student assignments that link the field trips to the classroom activities of the alpine/aeolian module:

- Take along the game board from Alpine/Aeolian Unit 1, Activity #3 “The Dating Game.” Have students see if they can locate sites on the game board from the various overlooks or interpretive exhibits.
- Have students identify characteristics of rocks they see along the trail. You may want to bring along a hand lens for this activity. (Do not break or remove rocks. Leave them in place for observations.)
- Take along photocopied sections of the roadway from a topographic map of Haleakalā National Park. Have students observe cloud patterns at different elevations and different times, or changes in vegetation patterns, and sketch their observations on the map.
- Have students identify plants they see in the summit area based on what they learned in Alpine/Aeolian Unit 3, Activity #1 “Alpine/Aeolian Challenges and Adaptations” and Activity #4 “Web of Life Game.”
- Using a topographic map and the background materials from Alpine/Aeolian Unit 5, Activity #2 “In-Class Public Forum,” have students locate the proposed site of the coordinated broadcast facility.
- Have students make journal entries reflecting their thoughts about the summit area, the Haleakalā Observatories and broadcast facilities, or the interpretive exhibits at the Visitor Center.



## Extensions

### Stay in the Wilderness

Take a group of students for an overnight stay at one of the wilderness cabins or campgrounds in Haleakalā National Park. Group size is limited to 12, including adults and students. Educational groups may reserve cabins and campground space up to six months in advance by sending a letter to Haleakalā National Park, P.O. Box 369, Makawao, HI 96768, Attn: Cabins. Submitting your request at least three months in advance increases the likelihood that your requested dates will be open. Call the park Environmental Education Coordinator at 572-4453 if you would like to arrange an educational program to accompany your visit.

### Offer Volunteer Service

Your class or school may volunteer for service projects through the Adopt-a-Trail and Adopt-a-Fence programs at Haleakalā National Park. You will be responsible for maintaining a specific stretch of trail or fence under this program. Find out more about these programs and other volunteer opportunities for individuals and small groups by contacting the park Volunteer Coordinator at 572-4487 or [HALE\\_VIP\\_Coordinator@nps.gov](mailto:HALE_VIP_Coordinator@nps.gov).



Alpine/Aeolian Unit 1

# Learning From the Mountain

## Overview

The geological features of the summit area of Haleakalā strongly influence the conditions under which plants, animals, and insects live in the alpine/aeolian zone. The history and influence of these features is not always easy to decipher. This unit helps students explore the geology of the summit area, focusing on what we can find out about the alpine/aeolian ecosystem and the geologic processes that shape it by observing and studying Haleakalā.

## Length of Entire Unit

Three class periods

## Unit Focus Questions

- 1) What can we learn about Haleakalā by studying its geological features?
- 2) What can we learn about the conditions for life in the alpine/aeolian ecosystem from studying the geological formations of Haleakalā?
- 3) How do geologists use science skills such as observation, hypothesizing, collecting data, and analysis to answer questions about Haleakalā?



## Unit at a Glance

### Activity #1

#### Haleakalā Past and Present

Students study the origin of Hawaiian volcanoes, including Haleakalā, and relate the history of these volcanoes to present conditions in the alpine/aeolian ecosystem.

#### Length

One class period, followed by a homework assignment

#### Prerequisite Activity

None

#### Objectives

- Make connections between environmental conditions in the alpine/aeolian ecosystem and the formation of Haleakalā.
- Describe basic characteristics and the process of formation of Hawaiian volcanoes, including plate tectonics.
- Compare a modern scientific explanation of the origin of the Hawaiian Islands with a traditional Hawaiian explanation.

#### DOE Grades 9-12 Science Standards and Benchmarks

FORCES THAT SHAPE THE EARTH: Students analyze the scientific view of how the Earth's surface is formed.

- Analyze how any of the Earth's Systems shapes the Earth.
- Relate the Theory of Plate Tectonics to our island formation, volcanic activity, and/or earthquakes.

### Activity #2

#### Haleakalā Detective Work

Students learn how geologists apply the scientific method to posing and answering questions about the past and future of Haleakalā and describe examples of hypothesis creation and testing.

#### Length

One class period, preceded and followed by a homework assignment

[Note: More time may be required for this activity if students have not met the Grades 4-5

Science Standard and Benchmark:

FORCES THAT SHAPE THE EARTH: Students analyze the scientific view of how the Earth's surface is formed.

- Explain the causes and effects of earthquakes and volcanoes.]

#### Prerequisite Activity

None

#### Objectives

- Describe how the ability to determine the age of lava flows using different methods is used to answer specific questions about Haleakalā.
- Explain the difference between a dating method that yields an absolute age and a comparative method.
- Explain and illustrate the process of radioactive decay and how it is used in determining the age of rocks.
- Hypothesize about the potential effects of a future eruption on the alpine/aeolian ecosystem of Haleakalā.

#### DOE Grades 9-12 Science Standards and Benchmarks

USING UNIFYING CONCEPTS AND

THEMES: Students use concepts and themes such as system, change, scale, and model to help them understand and explain the natural world.

- CHANGE: Explain the effect of large and small disturbances on systems in the natural world.



**NATURE OF MATTER:** Students examine the nature of matter.

- Analyze the interactions of molecules and their relationship to the physical properties of compounds in the context of biological, chemical, and/or physical systems.

**FORCES THAT SHAPE THE EARTH:** Students analyze the scientific view of how the Earth's surface is formed.

- Analyze how any of the Earth's Systems shapes the Earth.

## Activity #3

### The Dating Game

Students play a game in which they demonstrate their knowledge of the geology of Haleakalā and proper visitor behavior in the alpine/aeolian ecosystem.

#### Length

One class period

#### Prerequisite Activity

Activity #2 "Haleakalā Detective Work"

#### Objectives

- Demonstrate an understanding of:
  - Different techniques for determining the age of lava flows,
  - Basic geological facts about Haleakalā,
  - Characteristics of different volcanic products,
  - Cultural connections with the alpine/aeolian zone, and
  - Proper visitor behavior in the summit basin.

#### DOE Grades 9-12 Science Standards and Benchmarks

See Activity #2 standards and benchmarks.

## Enrichment Ideas

- Simulate the process of predicting volcanic eruptions by placing Alka Seltzer in water in a film canister and closing the lid. Before you do this, ask for predictions about what will happen after you cap the canister. Have students predict how much time it will take for the canister to "blow its top," then compare predictions to the actual elapsed time.
  - Link this activity to the general theme of the unit by explaining that geologists studying Haleakalā and other Hawaiian volcanoes are interested in when the volcanoes will erupt again. They gather clues from the layers of rock produced by past eruptions and use that evidence to help them predict when and where future volcanic activity is likely to occur. In making their predictions, scientists rely on basic science skills such as observation, discerning patterns, and sorting out likely effects of different variables.

Expand on this demonstration:

- Repeat the process several times using the same proportion of Alka Seltzer and water. Calculate the mean eruption time, and the range. Make the point that scientists can predict future eruptions based on past patterns, but there is still variation.
- Have students calculate the average error in their predictions using all of the data they collected. Then have them recalculate the average error, throwing out the data from the first round. Teaching point: The first round helped them "calibrate" their predictions, probably leading to more accurate predictions in the second and subsequent rounds.
- Mark film canisters with different colored labels and vary the amount of Alka Seltzer in each. Ask students to predict how long each will take to erupt. Then time and record each "eruption." Then do one final "eruption" without telling students how much Alka Seltzer you used. Have them estimate the quantity of Alka



Seltzer based on past observations. Teaching points: Different types of volcanoes and individual volcanoes at different stages of development have different eruptive patterns. Scientists compare current eruptions with past eruptions to learn about the volcano's stage of development.

- Brainstorm other variables that could affect the timing of the film canister "eruptions." These could include the fit of the lid, small variations in the amount of water or Alka Seltzer used, outside air pressure and temperature, and so forth. Then brainstorm a list of factors that might influence the timing and/or character of a volcanic eruption. Students may not know a lot about volcanoes, so this list may be quite general. You may need to give students clues. Use this brainstorm to set up the rest of the unit.
- Following the Activity #1 comparison of cinders to soil, have students design an experiment to compare the two as growing media for plants under different climatic conditions.
- Enlarge and photocopy the stages in the life of a Hawaiian volcano (p. 18), whitening out the numbers that indicate their sequence. Cut them apart and have students assemble these stages into the correct order as a thought experiment leading into the student reading "Haleakalā Detective Work."
- Have students select a topic about Hawaiian volcanoes and research it using Internet and print resources.
- Have students make an educational display and presentation about the formation of Hawaiian volcanoes and the geological history of Haleakalā for a younger class.

- While students are playing Activity #3 "The Dating Game," have them keep track of questions they miss. As homework, have students explain the correct answer to each question.

## Resources for Further Reading and Research

Hazlett, Richard W. and Donald W. Hyndman, *Roadside Geology of Hawai'i*, Mountain Press Publishing Company, Missoula, Montana, 1996.

Macdonald, Gordon A., Agatin T. Abbott, and Frank L. Peterson, *Volcanoes in the Sea: The Geology of Hawaii*, 2nd edition. University of Hawai'i Press, Honolulu, 1983.

*Hawai'i: Born of Fire*, NOVA video production, 1995. One hour in length. Order from 1-800-949-8670.

## Information About Hawaiian Volcanoes Available on the Following Websites:

Hawaiian Center for Volcanology at <[www.soest.hawaii.edu/GG/hcv.html](http://www.soest.hawaii.edu/GG/hcv.html)>.

U.S. Geological Survey Hawai'i Volcanoes Observatory at <[hvo.wr.usgs.gov](http://hvo.wr.usgs.gov)>.



Activity #1

# Haleakalā Past and Present

## ● ● ● Class Period One *The Influence of the Past on the Present*

### Materials & Setup

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- ‘O Wākea iā Papa Hānau Moku acetate (master, p. 9)
- Overhead projector and screen
- *Inside Hawaiian Volcanoes* video, Smithsonian Institution (provided with this curriculum)
- VCR

*For each group of four to six students*

- Small plastic bag of cinder (from a garden supply store)
- Small plastic bag of soil

*For each student (optional)*

- Student Page “*Inside Hawaiian Volcanoes Quiz*” (pp.10-11)

### Instructions

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- 1) Divide students into groups of four to six students. Give each group a bag of cinders and a bag of soil. Have them observe the contents of the two bags, write down a description of each, then write a comparison of the two.
- 2) Ask groups to share some of their responses.
- 3) Ask groups to write down an hypothesis about which would be easier for a plant to grow in and why. Again have groups share some of their responses. Help students consider the effects of the cinders’ porosity (inability to store water) and sharpness (danger of cutting fragile roots) on the ability of plants to grow.
- 4) Ask students whether an earthworm would do best in the soil or cinders. What about a spider? Have students explain their reasoning.
- 5) Ask whether anyone has been to the summit area of Haleakalā. Did they see cinders up there? How about soil? The substrate of the summit area largely consists of cinders and other volcanic products such as lava bombs. These rocks can tell us a lot about the past, present, and future of Haleakalā. They tell a story about the challenges of life in the summit area. They tell us something about the age of Haleakalā. As Hawaiian volcanoes reach a certain stage, their eruptions tend to become more explosive and they tend to eject more cinders than lava flows. And they may help scientists predict the general location and timing of future eruptions. Deciphering the secrets of Haleakalā and learning from the mountain are the themes of this unit. In order to learn about the present, we need to understand the past.





## Activity #1

### Alpine/Aeolian Unit 1

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- 6) Show the ‘*O Wākea iā Papa Hānau Moku*’ acetate. Read the chant aloud with students. Take the “one” role yourself or ask a student who is proficient in Hawaiian pronunciation to take that role. This chant illustrates one view of the origin of the Hawaiian Islands. Ask students to share ideas about how this chant compares with their understanding of the origin of the islands.
- 7) For another perspective, show the *Inside Hawaiian Volcanoes* video (25 minutes).
- 8) As homework, assign students the task of writing and/or illustrating how plate tectonics theory explains the formation of the Hawaiian Islands.

### Teaching Option

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- Instead of, or in addition to, the homework assignment, have students complete the Student Page “*Inside Hawaiian Volcanoes Quiz*.”

### Journal Ideas

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- How is the formation of the Hawaiian Islands explained in Hawaiian tradition? Write and/or illustrate your response, and keep in mind that there is more than one traditional explanation of the Islands’ origin. You may wish to find another version than the one presented in the chant you read during class.
- Compare the plate tectonics explanation of the formation of the Hawaiian Islands with a traditional Hawaiian explanation.

### Assessment Tools

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- Student writing and illustrations of the plate tectonics theory explanation of Hawaiian Islands formation
- Optional: Student Page “*Inside Hawaiian Volcanoes Quiz*” (teacher version, pp. 7-8)
- Journal entries



*Teacher Version*

## ***Inside Hawaiian Volcanoes Quiz***

- 1) What is the name of the rock that Hawaiian volcanoes are made of?

Hawaiian volcanoes consist almost entirely of a rock called basalt.

- 2) If the active volcano Lo‘ihi, now 914.6 meters (3000 feet) beneath sea level southwest of Kīlauea Volcano, has .3 meters (1 foot) of lava added to its summit each year, when will the volcano become an island?

A little over 3000 years from now

- 3) Geologists know that the increasing weight of a growing volcano progressively depresses or pushes down the underlying sea floor. How will this process affect the time needed for Lo‘ihi to become an island?

Lo‘ihi will require more time to become an island because of that process.

- 4) What is the geographic relationship between most active volcanoes and the boundaries of tectonic plates? Do the Hawaiian volcanoes conform to this general relationship? Why or why not?

Most active volcanoes are located along the boundaries between the crustal plates. These are locations where the processes of global plate tectonics favor the emergence of magma at the boundaries.

The Hawaiian volcanoes do not conform to this general situation and instead are near the center of the largest of all the crustal plates, the Pacific Plate. The Hawaiian volcanoes receive magma from a “melting spot” or “hot spot” in the mantle, 25 miles or more beneath the ocean floor. The reason for the existence of the hot spot is not known.



- 5) Hawaiian volcanoes swell or inflate before eruptions. How can the resulting change in shape of the ground surface be measured?

Inflation-caused change in shape (ground deformation) of Hawaiian volcanoes can be measured a) by leveling surveying stations to determine their change in elevation, b) by using an electronic distance-measuring instrument to determine changes in horizontal distance and, c) by leveling the corners of a triangle to determine changes in the slope or tilt of the ground surface.

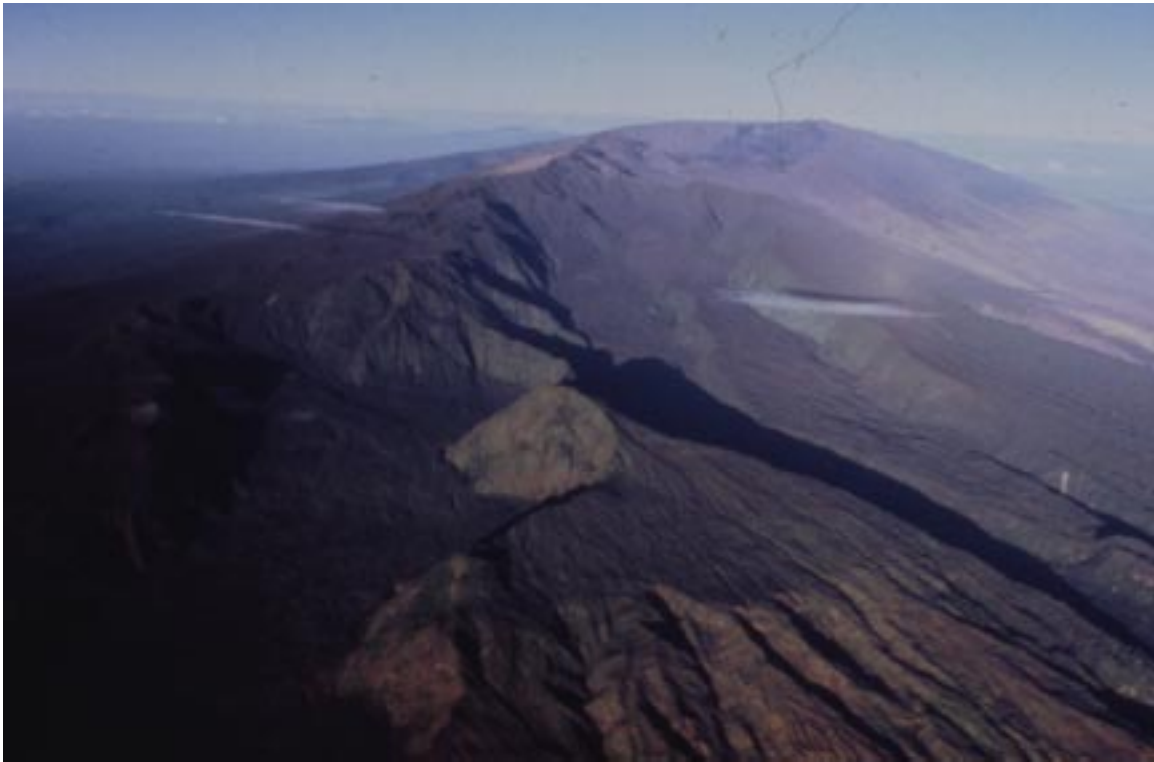
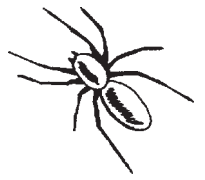
- 6) Most Hawaiian volcanoes are called shield volcanoes because of their broad, gentle profiles. Why do you suppose this shape is so common for Hawaiian volcanoes, in contrast to shapes of such steep-sided cones as Mount St. Helens and other high volcanic peaks in the Cascade mountain range of the Pacific Northwest?

Hawaiian lavas (basalt) flow far more easily (lower viscosity) than the lavas (andesite and dacite) of a volcano like Mount St. Helens. Flows of high fluidity tend to spread farther and thinner than the stickier (higher viscosity) Mount St. Helens lavas. In addition, a Hawaiian volcano erupts lava flows at many vent areas on its flanks (rift zones) as well as at the summit. This wide vent distribution helps to build a similarly wide volcano with a broad, gentle profile.

- 7) Which is older, the West Maui volcano or Haleakalā? Explain your reasoning.

The West Maui volcano is older. Reasoning may include:

- West Maui is more weathered and eroded than Haleakalā.
- Haleakalā is located southeast of the West Maui volcano. The Hawaiian Islands are progressively older to the northwest.



*Haleakalā from the air (Photo: The Nature Conservancy)*

## **‘O Wākea iā Papa Hānau Moku**

*(Malo/Traditional)*

One: *‘O Wākea noho iā Papa-hānau-moku*

All: *Hānau ‘o Hawai‘i, he moku  
Hānau ‘o Maui, he moku*

One: *Ho‘i hou ‘o Wākea noho iā  
Ho‘ohōkūkalani*

All: *Hānau ‘o Moloka‘i, he moku  
Hānau ‘o Lāna‘i ka ula, he moku*

One: *Lili-ōpū-punalua ‘o Papa iā  
Ho‘ohōkūkalani  
Ho‘i hou ‘o Papa noho iā Wākea*

All: *Hānau ‘o O‘ahu, he moku  
Hānau ‘o Kaua‘i, he moku  
Hānau ‘o Ni‘ihau, he moku  
He ‘ula a o Kaho‘olawe*

This chant talks about the birth of the Hawaiian Islands.

First is Hawai‘i and Maui born of the union between Wākea (Sky Father) and Papa (Earth Mother).

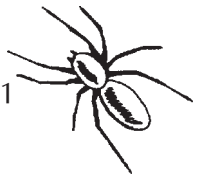
Then Wākea is with Ho‘ohōkūkalani (his daughter) and Moloka‘i and Lāna‘i are born.

Then Papa and Wākea have O‘ahu, Kaua‘i, Ni‘ihau and Kaho‘olawe.





- 5) Hawaiian volcanoes swell or inflate between eruptions. How can the resulting change in shape of the ground surface be measured?
- 6) Most Hawaiian volcanoes are called shield volcanoes because of their broad, gentle profiles. Why do you suppose this shape is so common for Hawaiian volcanoes, in contrast to shapes of such steep-sided cones as Mount St. Helens and other high volcanic peaks in the Cascade mountain range of the Pacific Northwest?
- 7) Which is older, the West Maui volcano or Haleakalā? Explain your reasoning.





Activity #2

# Haleakalā Detective Work

## ● ● ● In Advance *Student Reading and Questions*

- Assign the Student Page “Haleakalā Detective Work” (pp. 17-24) and “Haleakalā Detective Work: Questions About the Reading” (pp. 25-26).

## ● ● ● Class Period One *Detective Work Discussion*

### Materials & Setup

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- A piece of light-colored string about a foot long
- Several colored markers

### For each student

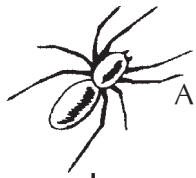
- Student Page “Haleakalā Detective Work” (pp. 17-24)
- Student Page “Haleakalā Detective Work: Questions About the Reading” (pp. 25-26)
- Student Page “The Dating Game: How Geologists Study the Age of Haleakalā Lava Flows” (pp. 27-31)

### Instructions

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- 1) To begin a discussion about the reading, ask students to share their responses to each of the four questions from the Student Page “Haleakalā Detective Work: Questions About the Reading.”
- 2) Ask for student questions about the reading. Be sure to review how radiocarbon (carbon-14) dating works to be sure that students understand the process and how it is applied to dating lava flows. This is important background for the next part of this activity.
- 3) Hand out the Student Page “The Dating Game: How Geologists Study the Age of Haleakalā Lava Flows.” Have students read the student page, skimming through the table that compares dating techniques (p. 31) for now. (Students will also take this student page home to read more carefully as homework.)
- 4) Use the information in the reading as background for a discussion of the difference between absolute dating methods, such as radiometric techniques, which yield a numeric age for rocks, and comparative methods such as paleomagnetic dating.
- 5) To illustrate the results of using a comparative technique, follow the instructions on pp. 29-30 of the reading to perform a demonstration using string and colored markers. Ask students to discuss what additional information would be needed to assign a correct date to a lava flow using a comparative method (e.g., cross checking against dates established through absolute methods, using the rule of superposition).
- 6) As homework, have students read the Student Page “The Dating Game” more carefully. Assign one or more of the journal entries as written homework as well.





## Journal Ideas

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- Describe the difference between a dating method that yields an absolute age and one that is comparative. Illustrate the difference using examples of things that you know for certain (and how you know or learned them) and knowledge that you've needed to cross-check before feeling confident about it. These examples could be from everyday life.
- Using drawings and/or writing, illustrate the process of radioactive decay. Explain why it is important in determining the age of rocks.
- Describe the environmental conditions created by the geology of the summit area of Haleakalā. How do you think plants and animals would be adapted to live in this environment?

## Assessment Tools

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- Student Page "Haleakalā Detective Work: Questions About the Reading" (teacher version, pp. 15-16)
- Participation in class discussions
- Journal entries



*Teacher Version*

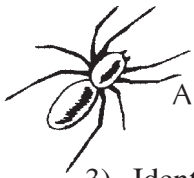
## Haleakalā Detective Work—Questions About the Reading

- 1) Why would Dave Sherrod be focusing on the lava laid down in the last 50,000 years to develop his “personality profile” of Haleakalā? Why isn’t he mapping the Kula Volcanic and Honomanū Basalt formations?

These are the lava flows produced during the most recent period of volcanic activity, in the volcanic life of Haleakalā. The patterns of these more recent flows should tell scientists more about what is likely to happen in the future than the patterns of volcanic activity in earlier stages (such as the alkalic capping stage, which corresponds to the Kula Volcanics, or the shield-building stage, which corresponds to the Honomanū Basalt).

- 2) Why does Dave Sherrod call radiocarbon dating “one of the worst ways to determine the age of a lava flow”? How does he make it work anyway?

Lava is not an organic (carbon-containing) substance, so the flows cannot be dated directly. In order to use radiocarbon dating, Dave finds charcoal under the lava flow and tries to figure out whether the charcoal was formed by that flow. Once he is confident of that, he performs the radiocarbon analysis on the charcoal and assigns that age to the associated lava flow.



- 3) Identify one hypothesis that Dave Sherrod is testing in his research and describe how he is testing it.

Possible answers include:

- There were never glaciers on Haleakalā. To test it, Dave has made calculations of the volcano's height over time by considering erosion, mountain building by eruptions, and subsidence. He correlated his calculations with the dates of the last ice age.
  - The scarcity of rocks between 200,000 and 50,000 years old is linked to the erosion that formed the summit basin of Haleakalā. To test it, Dave is looking for rocks that might help fill this time gap, in places where they may have been deposited by erosion such as the southwest rift zone and stream canyons near Ha'ikū, near Hāna, and in Kīpahulu Valley.
  - The Hāna formation lava flows were produced during the waning stages of the alkalic capping stage of volcanic activity. Based on chemical analyses, the rocks of the Hāna and Kula formations are indistinguishable. Dave and a Japanese graduate student are dating flows from the Kula Volcanics looking for long quiet periods within the Kula sequence that could set a precedent for the long lull that took place between production of the Kula and Hāna Volcanics.
  - Where and how will Haleakalā erupt again? Dave's just going to have to wait and see on this one!
- 4) A future eruption could take place in the Haleakalā summit basin. Describe the likely effects that an eruption of the type that Dave Sherrod anticipates would have on the plants and animals in the alpine/aeolian ecosystem.

Well-reasoned responses are acceptable. Dave predicts that the eruption will begin with an eruption of jagged cinder or spatter, along with ash, followed by lava flows. Large volumes of ash may blanket parts of the alpine/aeolian ecosystem, killing or displacing plant and animal life. Smaller parts of the ecosystem would be covered by the new cinder cone or the ensuing lava flows. Parts of the ecosystem will probably remain intact, especially if they are upwind from the ash plume and out of the path of the lava flow. Once the eruption has stopped, it will probably be a long time before significant plant growth is established on the new lava.



# Haleakalā Detective Work

Would you be interested in getting paid to pose questions, find ways to answer them, and then map out what you learned? How about working outdoors three to six months of the year? In a job that challenges you to be your own cartographer (map maker), photographer, and camp cook rolled into one?

If this sounds inviting, you might consider a career as a field geologist. As a field geologist, one of the jobs you might have is to make geological maps based on information collected outdoors, or “in the field.” Sound simple? It usually isn’t, says Dave Sherrod, a reconnaissance geologist who has studied Haleakalā since 1997. “But it *is* fun,” he adds.

## A Detective at Work

Dave describes his job as a detective game. “There’s a story here,” he explains. “But some of the pieces are missing. They’re buried or eroded away or we just don’t know where to look. Haleakalā doesn’t show its full hand to me. But the questions I’m asking can be answered if I’m careful enough in gathering clues and if I apply a variety of methods to understand the volcano.”

What kinds of mysteries has Dave Sherrod been trying to solve?

His main task is to map lava flows on Haleakalā to provide information about when the volcano might erupt again. His goal is to create a sort of personality profile of Haleakalā by looking at prehistoric and historic eruption patterns. According to Dave, this profile will help scientists forecast future activity. “Haleakalā seems to erupt every 200-500

years, but we need to verify that. We also need to know whether Haleakalā has a history of erupting at regular intervals or whether it erupts frequently for a while and then goes into long quiet periods.”

Dave will produce a series of maps of the youngest lava flows on Haleakalā, the ones laid down in the past 50,000 years or so. Several of these flows are younger than 1,000 years. Together, all of these flows younger than 50,000 years are known as the Hāna formation. It is commonly accepted that these flows were produced during the renewed volcanism or rejuvenation phase when Haleakalā returned to activity after a long lull. As you’ll find out later, this explanation is under scrutiny. [Figure 1 on page 18 contains more information about the life stages of Hawaiian volcanoes and the volcanic rock formations on Haleakalā.]

In order to produce these maps, Dave works with aerial photos and observations he makes on the ground to outline the edges of different flows, note the position of flows in relation to each other, and determine the source of each flow. In

order to make sense of that information, he needs to know the ages of the different flows.

Most often, Dave uses the “radiocarbon dating” technique to determine the age of rock samples he has collected in the field. This process uses the rate of radioactive decay of carbon-14 as a clock for determining the age of

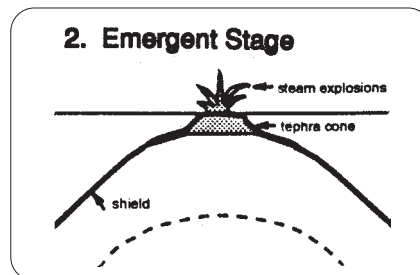
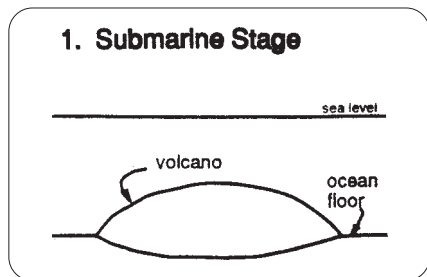
“organic” (carbon-containing) materials. But wait, you might be thinking, lava is *not* an organic substance! That’s one reason why Dave



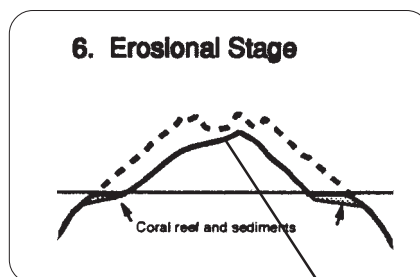
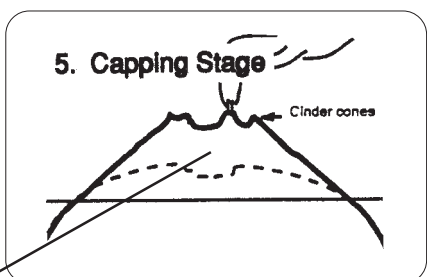
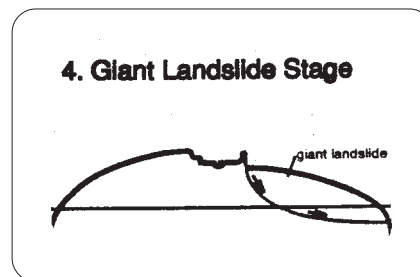
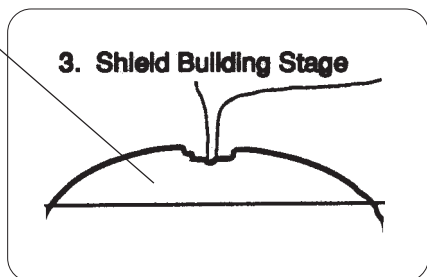
Dave Sherrod, middle, with a geology field crew  
(Photo: Sharon Ringsven)



Figure 1: Stages in the life of Hawaiian volcanoes

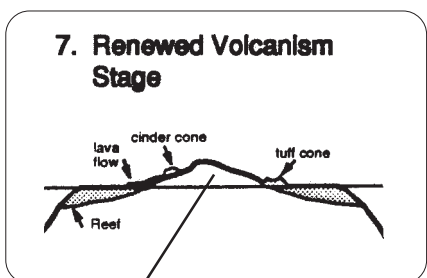


Honomanū Basalts

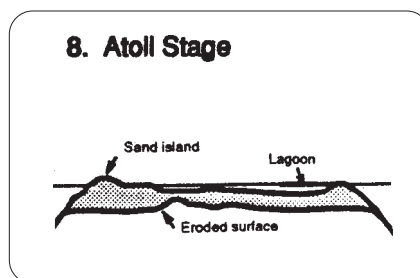


Kula Volcanics

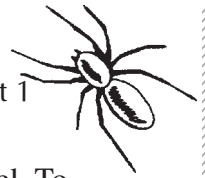
Summit basin was formed



Hāna Volcanics



Images: Haleakalā National Park



Sherrod calls radiocarbon dating “one of the worst ways to determine the age of a lava flow.”

Radiocarbon dating (or carbon-14 dating) works only if the geologist can find charcoal—the remains of tree trunks, plant roots or stems, and other plant parts that were burned by the lava as it flowed across the landscape. “First,” Dave says, “I have to get *under* the lava flow and find charcoal. Then I have to convince myself the charcoal was formed by the lava flow.” The radiocarbon analysis is done on the charcoal, and the age of the associated lava flow is based on the results of that analysis.

Even though carbon-14 dating can be a difficult technique to apply to dating lava flows, for Dave’s project, it is a good option. The lava flows he is mapping are younger than 50,000 years old, and radiocarbon dating is most accurate when used on organic materials younger than about 40,000 years. Because carbon-14 decays at a predictable rate, the radiocarbon technique usually provides reliable estimates of age and can be used by itself without using other techniques to cross-check results. Plus, through trial and error, Dave’s become a pro at finding charcoal even in rubbly ‘a‘ā flows—a task that many geologists deem next to impossible.

## Unsolved Mysteries

Dave Sherrod professes to enjoy few activities more than “walking around on lava flows all day, scratching my head and coming up with more questions and ways to address them.” One can think of Dave’s job as “interrogating” the rocks, using observation, careful data collection, and clear reasoning to hear and decipher the stories the rocks can tell. Here are some of the questions that Dave has been exploring in the course of gathering information for his “personality profile” of Haleakalā:

At its peak height, how tall did Haleakalā stand?

Today, Haleakalā stands 3056 meters (10,023 feet) above sea level, with only about five percent

of the volcano’s volume above sea level. To estimate the former height of Haleakalā, Dave needed to consider three main factors:

- 1) Erosion that happens over time,
- 2) Mountain building by eruptions, and
- 3) Subsidence—the sinking of the mountain’s mass into the earth’s crust. [Figure 2 on page 20 shows Dave’s estimates. ]

For Dave Sherrod, part of the fun of being a field geologist is that he gets to learn new technology, like the graphics software he uses to create images such as Figure 2 and the Geographic Information System (GIS) software he uses to compile his maps and more effectively share data with colleagues in other professions. “The technology helps me get information to people so they can understand it,” he says. “And I acquire a lot of new skills along the way!”

Were there ever glaciers on Haleakalā?

One reason scientists are interested in estimating the former height of the volcano is to determine whether glaciers may have helped shape the 915-meter-deep (3000-foot-deep) summit basin or “crater.” There is plenty of evidence for glaciation on Mauna Kea, but Haleakalā shows no evidence of the glacial till, moraines, or ice scouring that show up on Mauna Kea.

Because Haleakalā once rose much higher above sea level than it does now, some people have hypothesized that its summit, too, was covered by glaciers during the last ice age. Dave’s calculations suggest that, during the time of the last ice age, the Haleakalā summit was already too low in elevation to support glaciers.

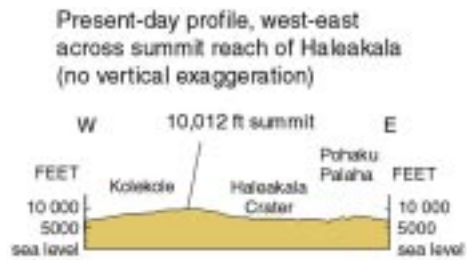
What happened to the lava that Haleakalā produced between 200,000 and 50,000 years ago?

Geologists began studying the volcanic history of Haleakalā in the 1930s. Based on that early research, geologists identified three main age

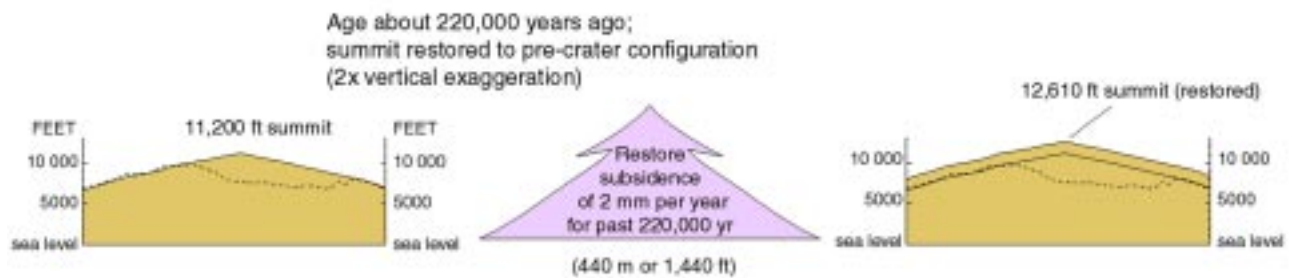


Figure 2: Reconstructing the height of Haleakalā through time

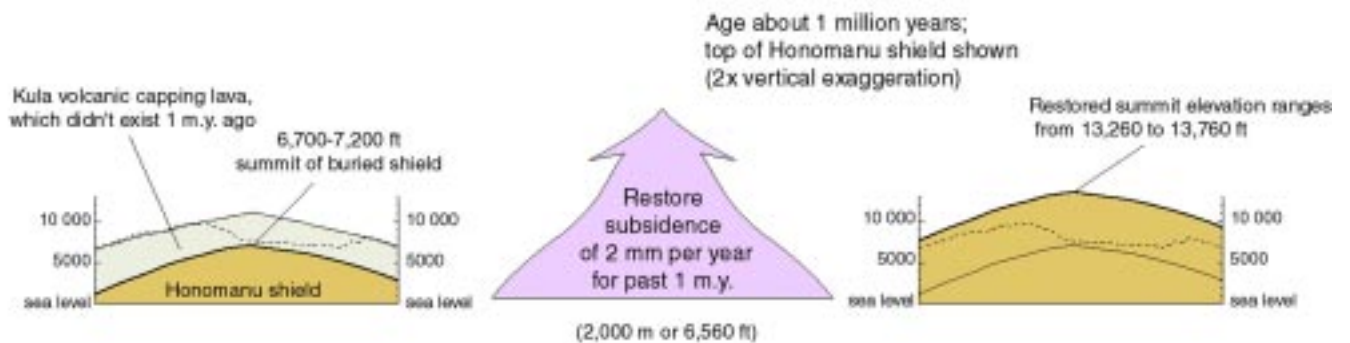
1. Present-day profile



2. Height 220,000 years ago estimated by 1) extending existing ridgelines to approximate pre-erosion summit, and 2) increasing height by 2mm per year to compensate for subsidence into the earth's crust.



3. Height one million years ago estimated by 1) “removing” approximately 2134 meters (7000 feet) of capping lava, and 2) increasing height by 2mm per year to compensate for subsidence.



Graphics: Dave Sherrod



classes of rocks on the volcano. These rocks seemed to differ from each other enough to suggest the volcano was in a different stage of its life cycle as each of these age classes was formed (see Figure 1).

Between the youngest rocks of the Kula Volcanics and the oldest rocks of the Hāna Volcanics, there is a perceived time gap. Few rocks have been dated that fit in this gap between 200,000 and 50,000 years ago. Dave Sherrod asked, “What happened during that time? Was the volcano completely quiet? Were the flows much smaller than the ones that came before and after, making it less likely to find rocks from that time? What else could explain this gap?”

One hypothesis Dave is testing is that the time gap is linked to the formation of the “crater” at the top of the mountain. The “crater” is actually a valley carved by streams during the erosional stage of the volcano. Collecting rock samples from the steep cliffs that surround the summit basin, Dave has found that they range in age from about 200,000 to 800,000 years old. That means that the “crater” was eroded away more recently than 200,000 years ago, then mantled by the younger flows (<50,000 years old) found on the floor of the basin.

During the interim period, Dave hypothesizes, the rate of erosion could have surpassed the rate at which lava was built up, especially if the flows were small and infrequent. Erosion could have stripped all of these intermediate flows from the summit basin. Dave has been looking for rocks that might help fill the lengthy time gap, in places such as the southwest rift zone, some stream canyons near Ha‘ikū, near Hāna, and in Kīpahulu Valley.

## What stage of volcanic activity is Haleakalā in?

One of Dave’s working hypothesis is that the Hāna formation was *not* produced during the rejuvenation stage of activity but actually represents the waning phases of the alkalic capping stage. The Kula volcanics are associated with this stage of activity. Chemical analyses performed since the 1980s have not been able to distinguish Hāna rocks from Kula rocks. So Dave hypothesizes that they were actually both produced during the same

stage of activity, when the chemical makeup of the rocks would have been similar.

Dave and a graduate student from Japan are looking for evidence to support this hypothesis. They are dating flows from the Kula Volcanics for evidence of long periods without eruptions *within* the Kula sequence. If they find this evidence, what now seems to be a long quiet period between two stages of activity could be explained as a long lull during the alkalic capping stage.

## When will Haleakalā erupt again?

“When it’s ready,” says Dave Sherrod. Even with all the work Dave’s been doing to profile the “personality” of Haleakalā, this is still a tricky question. Looking at the patterns of activity over the last 1,000 years, it could be that Haleakalā is overdue for an eruption. In the last 1,000 years, it has erupted 12-14 times, with an



*Dave Sherrod and Sharon Ringsven doing field work (Photo: Sharon Ringsven)*



*Tools of the trade: A core sample drill and rock hammer (Photo: Sharon Ringsven)*





average of 50-100 years between eruptions. Sometimes, these eruptions were as many as 400 years apart. Other eruptions happened just a few years apart.

Haleakalā is believed to have last erupted in 1790, but new information from dating the most recent lava flows suggests they may be about 400 years old. There is a good chance that Haleakalā will erupt again during the next 200 years. But, as Dave notes, “It’s unlikely the volcano follows a strict calendar. We’re certainly living in a time when none of us should be surprised if Haleakalā becomes restless and new eruptions ensue.”

Dave is more comfortable forecasting *where* Haleakalā will erupt next than *when*. “Almost certainly,” he notes, “the next eruption will begin somewhere along the rift zone, which is the axis of the volcano from Mākena to the summit and east to Hāna. It is less likely that a cinder cone will sprout as far as six kilometers on either side of the axis.”

When Haleakalā erupts again, Dave says, it will begin with an eruption of cinder or spatter. Ash will be borne on the wind into parts of the Central Valley and Upcountry. The lava flows that accompany this cone-building activity will probably be *‘a‘ā* or *pāhoehoe* that changes to *‘a‘ā*. The flows will move slowly enough to allow people to escape their path. There’s a good chance that the lava flows will reach the ocean, as they do from Kīlauea. This eruption may be as short as a few days, or as long as a couple years.

## Learning from the Mountain

Dave Sherrod and other geologists who study Haleakalā learn from the volcano’s past in part to understand what might happen in the future. But the past also offers windows on the present, and a way of understanding the alpine/aeolian ecosystem. The summit basin of Haleakalā is partially filled with lava and cinder ejected from cinder cones that span the floor of the

“crater.” According to Dave, the next eruption is likely to produce more cinder, spatter, and rumbly *‘a‘ā*—over time, perpetuating the conditions under which life exists in this ecosystem. The rumbly and coarse substrates hold little water and offer minimal organic nutrients for plants. In the dry and relatively cool climate of the summit area, organisms decompose slowly, making the process of soil formation in this relatively young landscape a long one.

Resource managers learn from the mountain, too. They discovered that plants, such as the *‘āhinahina*, growing on loose cinder slopes are susceptible to having their shallow, spreading roots cut by sharp and shifting cinders. Trampling by human visitors is a significant threat to these plants. Now Haleakalā National Park advises visitors to stay on trails to protect the native plants in this harsh, but fragile, environment.



*This lava flowed down an eroded channel. (Photo: John Flynn)*



## Coming to Terms With Volcanoes

Dave Sherrod and other field geologists work like detectives, piecing together stories and following hunches. Like detectives, they also study to learn more about what they are investigating. Here is some information that will help you understand the dynamics of Hawaiian volcanoes and the terminology Dave uses to describe what he expects from future eruptions of Haleakalā.

### What is a volcano?

A “volcano” is a place where magma (molten rock) and/or gas comes to the surface from within the earth’s core. Some volcanoes erupt only once. Others erupt many times over the course of millions of years. Most volcanic mountains are made up of the accumulated products of dozens or even hundreds of eruptions. All eruptions are not the same. Hawaiian volcanoes tend to have gentle eruptions, while other volcanoes erupt explosively. As volcanoes near the end of their life spans, their eruptions usually become more explosive.

### To explode or not to explode?

How explosive an eruption is depends largely on two main factors: gas content of the lava and its “viscosity” (or fluidity). Highly viscous lava is thick and sticky, making it difficult for gas to work its way to the surface. Gas tends to get trapped in the lava until the pressure is high enough to allow it to burst free (like shaking up a soda can and then opening it). In contrast, gas escapes more easily and gradually from low viscosity, fluid lava, creating eruptions with minimal spattering and explosion.

Viscosity is related to three main factors:

#### **Chemical composition: silica content**

In general, the higher the silica content, the higher the viscosity. Mount St. Helens, for example, erupted highly viscous lava with high silica content.

#### **Temperature**

Cooler lava is more viscous than hotter lava.

### Gas content

Lava with lower gas content is more viscous than lava that contains more gas.

### You’re outta here

Any fragments of lava or already-solidified rock that are thrown into the air (or ejected) by a volcanic explosion are called “volcanic ejecta.” As volcanic gas escapes at the earth’s surface, it carries fragments of magma with it, and sometimes older, solidified rocks, too. Violent explosions may carry large amounts of material high into the air scattering fragments close to the vent or far away, depending on their size and the explosiveness of the eruption. These fragments are of “pyroclastic” (fire-broken) origin. They are also called “tephra.”

Ejecta are classified according to size, and the larger fragments are also classified according to how fluid they were when they were ejected. Here are three types Dave expects to see if he’s around when Haleakalā next erupts:

#### **“Cinder”**

Smaller than four centimeters (1.6 inches) in diameter; frothy fragments with highly irregular shapes

#### **“Volcanic ash”**

Less than .5 centimeters (.2 inch) in diameter; ash may be bits of already-solid rock, crystals from solid rock, or particles of lava that were thrown up as liquid spray.

#### **“Spatter”**

Expanding gasses in lava fountains of Hawaiian-type eruptions tend to tear the liquid into irregularly shaped globs that fall in heaps around the vent. Many of the fragments are still partly liquid when they strike the ground. They flatten out or splash when they hit, forming spatter.

### Cinder and spatter cones

The hill built by fragments falling around the vent will often take the shape of a cone with a crater at the summit. Spatter cones are made up



of, you guessed it . . . spatter. Cinder cones are made up of cinders and some spherical, ribbon, or spindle bombs.

## Lava flows

When liquid magma pours out of the ground, it can form lava flows. There are two types of Hawaiian lava flows — “*pāhoehoe*” and “*‘a‘ā*.” *Pāhoehoe* has smooth, billowy, or ropy surfaces. *‘A‘ā* has a very rough, spiny, or rubbly surface. *Pāhoehoe* is the more “primitive” of the two types. In other words, most flows emerge from the vent as *pāhoehoe*, often changing to *‘a‘ā* as they move downslope. *The reverse change, from ‘a‘ā to pāhoehoe, does not happen.* The more viscous the lava, the greater its tendency to change to *‘a‘ā*.

Both types of lava contain “vesicles”—holes left behind when the lava cooled quickly and trapped gases. Vesicles in *pāhoehoe* generally have a regular, round shape. Vesicles in *‘a‘ā* tend to have twisted, irregular shapes. This occurs because the high fluidity of *pāhoehoe* lava allows the gas bubbles to keep their spherical shapes while gas bubbles in the more viscous *‘a‘ā* are easily deformed.

Hawaiian lava tends to be highly fluid, resulting in rapid movement of the flows.







# The Dating Game: How Geologists Study the Age of Haleakalā Lava Flows

A question that has fascinated geologists since the field of study began is, How old is the earth? As scientists used fossil evidence to piece together a record of the evolution of life on this planet, they created a standard “geologic time scale.” On this time scale, groups of similar fossils (“fossil assemblages”) are used as a basis for dividing time into four broad eras, each of which is subdivided into periods and shorter epochs. The geologic time scale is “relative.” That means that it tells the relationship of these epochs, periods, and eras to each other—not how long each lasted or how long ago they began.

Many geologists were not content to know only that the Paleozoic era came before the Mesozoic, or that the Jurassic period followed the Triassic.

They were interested in “absolute age,” in determining a numeric age for the rocks in which fossils are contained. The ability to make these determinations has come only in the handful of decades since the discovery of “radioactivity” (a property possessed by some elements in which streams of charged nuclear particles are emitted due to the disintegration of the nuclei of atoms). The development of reliable techniques for “radiometric dating” (establishing an age based on changes in atomic structure) has given



Photo: John Flynn

geologists the ability to calculate the age of rocks and minerals that range from very young to billions of years old.

Some of the same techniques that scientists used to put dates on the divisions of geologic time have also helped geologists determine the age of the lava flows that make up Haleakalā. Determining the age of the lava flows helps them understand more about the life cycle of Hawaiian volcanoes and be able to determine the risks of future eruptions.

## Radiometric Dating Techniques

All radiometric dating techniques use the same general principles. When minerals are newly

crystallized, as they are when magma erupts at the surface and lava flows, they seal in radioactive isotopes. Then the process of “radioactive decay” begins (see page 29 for an explanation of isotopes and radioactive decay). The rate of decay for many elements has been precisely measured and is

constant for each element, so radioactivity works like a clock. Scientists determine the ratio of a radioactive element to its decay products to calculate how long ago the mineral crystallized.



## What makes radiometric dating work?

An atom is classified as a particular element based on the number of protons in its nucleus. Uranium atoms, for example, contain 92 protons. Carbon atoms contain 6. The number of neutrons may vary, however. The “isotopes” of an element have the same number of protons, but different numbers of neutrons. Potassium, for example, has three naturally occurring isotopes, each named for its mass number (the total number of protons and neutrons in the nucleus): K-39, K-40, and K-41.

Of the three potassium isotopes, only one is radioactive. K-40 atoms have unstable nuclei, which spontaneously break apart in a process known as “radioactive decay.” This process involves the formation of “daughter products” (atoms that result from radioactive decay) from the original parent isotope. K-40 disintegrates at a constant rate that scientists measure in terms of half-life. A half-life is the time required for one-half of the nuclei in a sample to decay. There are radioactive isotopes of many elements. Each has its own rate of decay and therefore its own half-life. If the half-life of an isotope is known, the age of a material containing that isotope can be calculated by measuring the proportion of the parent isotope to the daughter isotope.

The basic principle behind radiometric dating is simple and based on straightforward calculations. In practice, however, radiometric dating is a complicated procedure requiring careful sampling, precise chemical analysis, and an exact knowledge of how radioactive isotopes break down into stable daughter products. For some isotopes, the process of radioactive decay produces several unstable daughter products before the stable daughter product—which will not decay immediately into another isotope—is formed. Each of these unstable intermediate products has its own half-life.

The radiometric dating done directly on rock samples from Haleakalā has been “potassium-argon dating.” The radioactive isotope used in this technique is potassium-40, which has a half-life of 1.3 billion years. Its stable daughter product (the final result of radioactive decay, which does not break down further) is argon-40. Because potassium-40 has such a long half-life, this dating technique can be used to determine the age of very old rocks. It has been used to date samples collected from the face of lava flows revealed by erosion in the walls of the Haleakalā “crater.” These rocks ranged in age from about 200,000 years to about 800,000 years old!

For the younger lava flows on Haleakalā, another type of radiometric dating is important. “Radiocarbon” dating is not done on rocks

themselves, but on the remains of plants or animals associated with the rock formations a geologist wants to date. On Haleakalā, geologists look for charcoal—roots or stems from plants that were incompletely burned when the lava flow passed over or around them. These remains contain carbon-14, an unstable carbon isotope that can be used reliably to determine ages up to about 50,000 years.

## Paleomagnetic Dating

Similar to potassium-argon dating, “paleomagnetic dating” works with a sort of clock that is set when lava cools and solidifies. Lava flows contain minerals that record the orientation of the earth’s magnetic field at the time they form. The earth’s magnetic field changes over time, with the



magnetic north pole shifting around and sometimes completely reversing. A compass reading would indicate north as a different direction today than it would have ten or 1000 or 10,000 years ago. This change is known as “magnetic secular variation.”

Paleomagnetic dating is a “comparative technique.” This means that a magnetic history of the area needs to be established before the ages of undated flows can be determined. This is done by taking samples from lava flows that have been dated using other methods such as radiocarbon dating. The magnetic orientation of these samples is used to develop a history of how the earth’s magnetic orientation has changed over time. Many samples from Kilauea, Mauna Loa, and Haleakalā have been used to create a magnetic variation curve for the Hawaiian Islands. New samples from undated flows can be compared to this curve and their ages estimated.

Properly speaking, the paleomagnetic technique will not provide a date for the lava flow. By relating the sample’s alignment to the record of past changes in the magnetic field, scientists can narrow down the possible age of the rock so they can use other clues to decide which of the possible ages is most reasonable. The reason for this

lack of certainty is that, as the earth’s magnetic pole wanders, it often crosses paths with itself, showing the same orientation as it did thousands or even hundreds of thousands or more years previous.

### Show Yourself

Take a piece of string about a foot long. Lay it down on a table, looping it around so it crosses over itself a few times. This represents the established magnetic variation for an area over time, say 30,000 years. (See the generalized magnetic variation path in Figure 2 for an idea of the kind of looping and crossing you are trying to make.) Mark each point where the string crosses itself with a different color pen or marker—one with red, one with blue, one with black, or whatever colors you have on hand. At each intersection, make sure you mark both the upper and lower strings with the same color.

Imagine that you are trying to date a lava flow, so you take a sample. When the paleomagnetic analysis is complete you learn that the magnetic orientation in the lava corresponds with one of the places on your magnetic variation curve where the string overlaps itself. Let’s say that the color you’ve used to mark this overlap is red.

Figure 1: Illustrations of how the magnetic north pole “wanders” over time

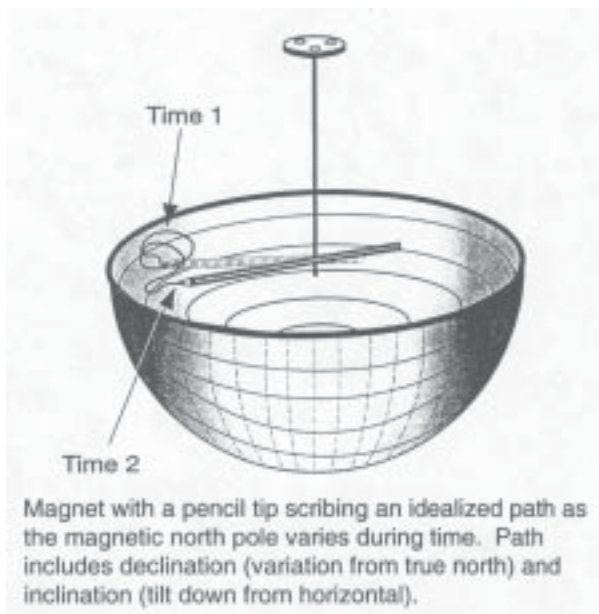
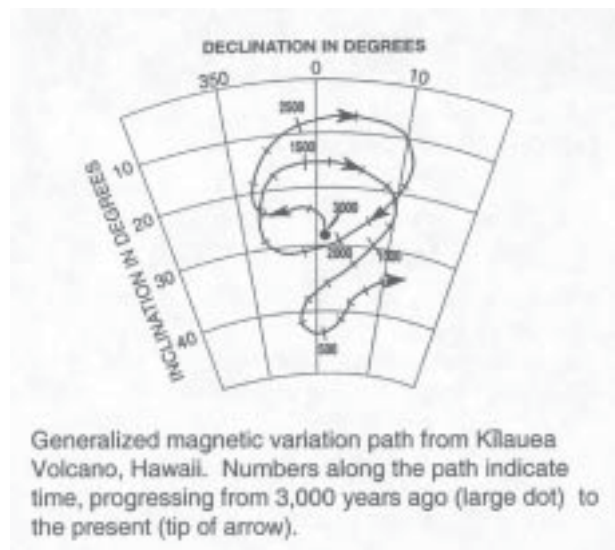


Figure 2: Magnetic variation path



Images: Haleakalā National Park





word, “present.” At the other end of the string, write “30,000.” Now you’ve made your string into a timeline that represents the last 30,000 years. Estimate the age represented by the two red marks on this timeline and write them down on the piece of paper, near each red mark.

How would you know which of the red marks represents the age of your lava sample? You would not know, based only on the paleomagnetic analysis. The paleomagnetic analysis would tell you only that your rock sample is one of two ages, perhaps 5000 or 15,000 years old. At that point, you would need to use other means for figuring out which is the correct age.

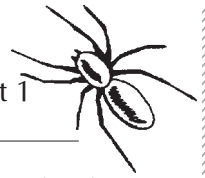
### Cross Checking

One way you could tell whether your rock sample is 5000 years old or 15,000 years old is to look at the lava flow in relationship to other lava flows. If a flow above or below it has been dated, you can use the rule of superposition to help you narrow down the correct age. The rule of superposition states that unless the rock layers have been disturbed, the older layers will lie underneath the younger layers. So if the lava flow you are trying to date lies *underneath* a flow that has been radiocarbon dated at 8000 years old, you can be confident that your sample is 15,000 years old rather than 5000.

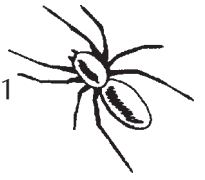
Cross checks such as these are important for all dating techniques. Since the analyses required for all of the dating techniques are so complicated, it is important to check results against other ways of determining the ages of rocks to assure accuracy.



*Geologist removes a core sample for paleomagnetic dating.  
(Photo: Sharon Ringsven)*



Dating Technique	How It Works	Strengths & Weaknesses
Potassium-argon	<p>Scientists measure the proportion of K-40 (an unstable isotope of potassium) to Ar-40 (a daughter product, a stable isotope of the inert gas, argon). K-40 converts to Ar-40 when the K-40 nucleus captures one of its orbiting electrons. The electron's negative charge neutralizes one proton, which becomes a neutron. With one less proton in its nucleus, what was once a potassium atom (atomic number 19) is now an argon atom (atomic number 18). The half life of K-40 is 1.3 billion years.</p>	<ul style="list-style-type: none"> <li>•Is useful for dating rocks because potassium is abundant in many common minerals</li> <li>•Can be used to date old rocks, over 100,000 years old</li> <li>•Is accurate only when the potassium-bearing mineral remained in a closed system since its formation (Since argon is a gas, it may leak out of the minerals in which it forms. Significant losses can occur when the rock is subjected to high temperatures. Scientists must look for fresh, unweathered samples.)</li> </ul>
Radiocarbon Carbon-14	<ul style="list-style-type: none"> <li>• Carbon-14 is produced when high-energy nuclear particles known as cosmic rays bombard the upper atmosphere. In this bombardment, the nuclei of gases are shattered, releasing neutrons. The neutrons are absorbed by nitrogen atoms (atomic number 7), causing the nucleus to emit a proton. A new element, carbon-14 is formed (atomic number 6).</li> <li>• Carbon-14 is an unstable isotope which circulates in the atmosphere and is absorbed by all life forms. As long as the organism lives, the decaying C-14 is continually replaced, maintaining consistent proportions of C-14 to C-12, the more common, stable carbon isotope.</li> <li>• When the organism dies, C-14 is no longer replaced, and C-14 atoms decay to N-14 by emitting a single electron, after which one of the neutrons takes on a positive charge (i.e., becomes a proton).</li> <li>• The ratio of C-14 to C-12 decreases at a constant rate (the half-life of C-14). Radiocarbon dating measures that ratio to determine the age of the material. The half-life of C-14 is 5730 years.</li> </ul>	<ul style="list-style-type: none"> <li>•Carbon-14 is common. It is found in the remains of all living things.</li> <li>•Can be used reliably on organic matter less than 50,000 years old</li> <li>•Is tricky to use on rocks, since C-14 does not occur in rocks (The scientist must be careful to establish with great certainty that the charcoal or other organic remains being dated are from the same time period as the lava flow in question.)</li> <li>•Is difficult to use on lava flows because finding charcoal is difficult, if not impossible, at many lava flows (In some places, the base of the flow is not exposed. In others, there was no vegetation prior to the lava flow. And in others, there is not enough charcoal remaining to use for dating.)</li> </ul>
Paleomagnetic	<p>When minerals are heated above 650° C, they lose their magnetic orientation. When magma cools to form solid volcanic rock, the alignment of these minerals is “locked in” to the earth’s magnetic orientation at the time of cooling. By matching the magnetic orientation of a carefully taken rock core with the magnetic history of an area, scientists can narrow down the possible age of the sample.</p>	<ul style="list-style-type: none"> <li>•Can be used on rocks that scientists have been unable to date with other techniques such as radiocarbon</li> <li>• Is useful for lava rock, which is rich in magnetic minerals</li> <li>•Is a comparative technique that must be calibrated to rocks with known ages (The magnetic history of an area is produced by analyzing rocks that have been dated using other techniques.)</li> <li>•Does not always produce a definite age, but does help narrow down the possibilities</li> </ul>





Activity #3

# The Dating Game

## ● ● ● In Advance *Game Preparation*

- Prepare game cards (master, pp. 35-48) by copying, cutting apart, and folding each in half along the dotted line. In this way, you will create a “front” and “back” of the card. The front will have only the card type and corresponding shape on the game board. The back will contain the question, answer, and/or playing instructions. You may wish to laminate these cards, as well as an instruction card for each group.

## ● ● ● Class Period One *The Dating Game*

### Materials & Setup \_\_\_\_\_

*For each group of up to six students*

- Game board (provided with this curriculum)
- 1 die
- Game instructions card (master, p. 34)
- Game cards (master, pp. 35-48)
- Six player pieces (small objects such as buttons, stones, or shells that can be easily distinguished)

### Instructions \_\_\_\_\_

- 1) Conduct the game with groups of up to six students each. Use the game materials provided with the curriculum and “The Dating Game Instruction Card.”

### Assessment Tools \_\_\_\_\_

- Participation in the game
- Optional: During the class period following the game, use some of the game cards to conduct an in-class written quiz. Draw cards randomly or select them in advance.



## The Dating Game Instruction Card

The game begins at Sliding Sands Trailhead, follows the trail to Palikū, and ends at Halemau‘u Trailhead. Move your player pieces by the roll of the die, answering questions, and/or following instructions given on the game cards. The first player to Halemau‘u Trailhead wins!

Once you have used a game card, put it on the bottom of the pile it was drawn from.

Each player rolls the die **once** per turn and draws **one card**. Play advances **clockwise**.

When you land on a space, follow the symbol.

Here’s what happens:

### **A, B, C, D = Special Interest!**

Draw the corresponding card. Use clues provided to locate the site on the game board/map and read the card to the other players.

Locate the site on the map = **Move forward 3 spaces**

### **1-7 = Dating Sites**

Follow the arrow to the corresponding dating site.

Read aloud the card with the matching number.

After reading the card, **follow the arrows back to the trail.**

### **TM = Dating Questions**

Another player draws a card and reads you the question on it. You try to answer the question.  
Movement

Correct answer = **Move forward 2 spaces.**

Incorrect answer = **Move back 1 space.**

### **n = Landforms & Volcanic Products**

Another player draws a card and reads you the question on it. You try to answer the question.

Correct answer = **Move forward 2 spaces.**

Incorrect answer = **Move back 1 space.**

### **H = Risks & Challenges**

Another player draws a card and reads you the instructions on it. There are two kinds of cards:

- Situational cards: You choose the correct answer from 3-4 choices.  
Incorrect answer = **Move back 1 space.**
- Potluck cards: You have no control here!  
**Follow the directions on the card.**

### **U = Double Jeopardy**

Choose to risk 2, 4, or 6 spaces before you hear the question. Then listen to the question and answer it.

Correct answer = **Move forward number of spaces risked.**

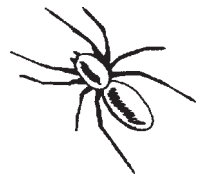
Incorrect answer = **Move backward number of spaces risked.**

### **l = Connector Trails**

You may choose to take a “connector” trail. Another player draws a card and reads you the question. You try to answer it. To cross the connector trail, answer a question correctly for each space on the trail.

Correct answer = **Move forward one dot on the connector trail.**

Incorrect answer = **Go back to where you started on the main trail and continue down the normal trail.**



The Dating Game Cards (cut on solid lines, fold on dashed lines)

<p style="text-align: center;"><b>A</b> <b>Special Interest</b></p>	<p style="text-align: center;"><b>B</b> <b>Special Interest</b></p>
<p>High atop the <i>pali</i> at Haleakalā, the Kilohana area is an archeological site. This site has basalt lava flows and was used for an adze quarry.</p>	<p>Up on the rim of the summit basin or valley sit the remnants of a <i>heiau</i>. This <i>heiau</i> is located due south of Pu‘u o Pele.</p>
<p style="text-align: center;"><b>C</b> <b>Special Interest</b></p>	<p style="text-align: center;"><b>D</b> <b>Special Interest</b></p>
<p>Pōhaku Pālaha is a point on Haleakalā where the <i>ahupua‘a</i> boundaries are determined for the east side of Haleakalā.</p>	<p>Lava tubes, rock crevices, and other sites were areas commonly used as burial sites for <i>piko</i> (umbilical cords) and for burials.</p>




The Dating Game Cards (cut on solid lines, fold on dashed lines)

<p style="text-align: center;"><b>1</b> <b>Dating Site</b></p>	<p style="text-align: center;"><b>2</b> <b>Dating Site</b></p>
<p>A paleomagnetic dating technique was used to date the youngest flow from Ka Lu‘u o ka ‘Ō‘ō. The results came back inconclusive. However, based on relative ages of surrounding flows, we know this flow is younger than 970 years and probably younger than 900 years.</p>	<p>This flow on the south rim of the “crater” was dated using a radiocarbon method. It is estimated to be 3750 (+/- 50) years old.</p>
<p style="text-align: center;"><b>3</b> <b>Dating Site</b></p>	<p style="text-align: center;"><b>4</b> <b>Dating Site</b></p>
<p>A carbon-14 dating technique was used here on this flow from Pu‘u Maile. A date of 4070 (+/- 50) years ago was determined. This flow was dated using the paleomagnetic method as well. That method came up with an age of around 4000 years.</p>	<p>Kālua ‘Awa is one of the few <i>pāhoehoe</i> flows within the “crater.” This flow was dated by both the radiocarbon and the paleomagnetic techniques. An age of 1040 (+/- 40) years was determined.</p>







The Dating Game Cards (cut on solid lines, fold on dashed lines)

<p style="text-align: center;"><b>5</b> <b>Dating Site</b></p>	<p style="text-align: center;"><b>6</b> <b>Dating Site</b></p>
<p>The Hanakauhi fissure produced the youngest flow dated on the east side of the summit basin. This flow has an age of 870 (+/- 40) years, based on both a radiocarbon and a paleomagnetic analysis.</p>	<p>A paleomagnetic dating technique was used for Pu'u o Māui. The approximate age of this flow is 3000 years.</p>
<p style="text-align: center;"><b>7</b> <b>Dating Site</b></p>	<p style="text-align: center;"> <b>Dating Card</b></p>
<p>An older flow from Ka Lu'u o ka 'Ō'ō was dated both by carbon-14 and paleomagnetic analyses. The flow is estimated to be 970 (+/- 50) years old.</p>	<p><b>Question</b> Paleomagnetic drilling works because which components of rocks align to the magnetic orientation of the poles when heated to high temperatures?</p> <p><b>Answer</b> Minerals</p>





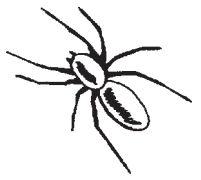
The Dating Game Cards (cut on solid lines, fold on dashed lines)

 <p><b>Dating Card</b></p>	 <p><b>Dating Card</b></p>
<p><b>Question</b> Why might lava flows at high elevations not be able to be dated by radiocarbon methods?</p> <p><b>Answer</b> These lava flows have very little organic matter associated with them, which is what the carbon-14 method dates.</p>	<p><b>Question</b> What type of material is used to date flows using the radiocarbon method?</p> <p><b>Answer</b> Organic material (such as plants, stems, roots, trunks)</p>
 <p><b>Dating Card</b></p>	 <p><b>Dating Card</b></p>
<p><b>Question</b> Radiocarbon dating is most accurate on flows with organic materials less than how old?</p> <p><b>Answer</b> 50,000 years old</p>	<p><b>Question</b> Name the three types of dating processes used on Haleakalā.</p> <p><b>Answer</b> Radiocarbon (or carbon-14), Paleomagnetic, Potassium-Argon</p>



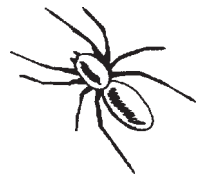
The Dating Game Cards (cut on solid lines, fold on dashed lines)

<p style="text-align: center;"><b>n</b></p> <p style="text-align: center;"><b>Landforms &amp; Volcanic Products</b></p>	<p style="text-align: center;"><b>n</b></p> <p style="text-align: center;"><b>Landforms &amp; Volcanic Products</b></p>
<p><b>Question</b> What is the most probable hypothesis about how the summit basin or valley formed?</p> <p><b>Answer</b> Erosional processes</p>	<p><b>Question</b> What are two of the three kinds of volcanic ejecta that Dave Sherrod expects to see from the next eruption of Haleakalā?</p> <p><b>Answer</b> Two of these: cinder, spatter, ash</p>
<p style="text-align: center;"><b>n</b></p> <p style="text-align: center;"><b>Landforms &amp; Volcanic Products</b></p>	<p style="text-align: center;"><b>n</b></p> <p style="text-align: center;"><b>Landforms &amp; Volcanic Products</b></p>
<p><b>Question</b> Can an 'a'ā flow turn into <i>pāhoehoe</i>?</p> <p><b>Answer</b> No</p>	<p><b>Question</b> What chemical element determines higher or lower viscosity?</p> <p><b>Answer</b> Silica</p>



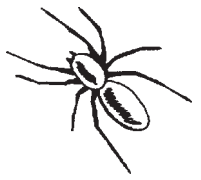
The Dating Game Cards (cut on solid lines, fold on dashed lines)

<p style="text-align: center;"><b>u</b></p> <p style="text-align: center;"><b>Landforms &amp; Volcanic Products</b></p>	<p style="text-align: center;"><b>u</b></p> <p style="text-align: center;"><b>Landforms &amp; Volcanic Products</b></p>
<p><b>Question</b> What is the <b>youngest</b> volcanic formation on Haleakalā?</p> <p><b>Answer</b> Hāna Volcanic formation</p>	<p><b>Question</b> Name the three volcanic formations of Haleakalā.</p> <p><b>Answer</b> Honomanū Basalt, Kula Volcanic, Hāna Volcanic</p>
<p style="text-align: center;"><b>u</b></p> <p style="text-align: center;"><b>Landforms &amp; Volcanic Products</b></p>	<p style="text-align: center;"><b>u</b></p> <p style="text-align: center;"><b>Landforms &amp; Volcanic Products</b></p>
<p><b>Question</b> What is the oldest volcanic formation of Haleakalā?</p> <p><b>Answer</b> Honomanū Basalt</p>	<p><b>Question</b> What <b>two</b> factors will determine whether or not an eruption will be explosive or more gentle?</p> <p><b>Answer</b></p> <ul style="list-style-type: none"><li>•Viscosity or fluidity of lava</li><li>• Gas content of lava</li></ul>



The Dating Game Cards (cut on solid lines, fold on dashed lines)

<p style="text-align: center;"><b>n</b></p> <p style="text-align: center;"><b>Products</b></p> <p style="text-align: center;"><b>Landforms &amp; Volcanic</b></p>	<p style="text-align: center;"><b>n</b></p> <p style="text-align: center;"><b>Products</b></p> <p style="text-align: center;"><b>Landforms &amp; Volcanic</b></p>
<p><b>Question</b> Define volcanic ejecta.</p> <p><b>Answer</b> Any solidified lava fragment thrown into the air by a volcanic explosion</p>	<p><b>Question</b> Define cinders.</p> <p><b>Answer</b> Volcanic ejecta less than 4 cm in diameter (Other answers may include “frothy” volcanic ejecta with irregular shapes.)</p>
<p style="text-align: center;"><b>n</b></p> <p style="text-align: center;"><b>Products</b></p> <p style="text-align: center;"><b>Landforms &amp; Volcanic</b></p>	<p style="text-align: center;"><b>H</b></p> <p style="text-align: center;"><b>Risks &amp; Challenges</b></p>
<p><b>Question</b> This lava is ejected in irregularly shaped globs that fall in heaps around the vent. They flatten out or splash when they hit. What is this type of ejecta called?</p> <p><b>Answer</b> Spatter</p>	<p>You go off the trail, fall into a lava tube, and break your leg.</p> <p><b>Go back to Start.</b></p>



The Dating Game Cards (cut on solid lines, fold on dashed lines)

<p style="text-align: center;"><b>H</b></p> <p style="text-align: center;"><b>Risks &amp; Challenges</b></p>	<p style="text-align: center;"><b>H</b></p> <p style="text-align: center;"><b>Risks &amp; Challenges</b></p>
<p>You fed a <i>nēnē</i>, encouraging it to bother other humans for food that's not in its natural diet.</p> <p><b>Go back 5 spaces.</b></p>	<p>You climb over the railing at Kawilinau (the Bottomless Pit). You fall in and have to be rescued.</p> <p><b>Go back to Start.</b></p>
<p style="text-align: center;"><b>H</b></p> <p style="text-align: center;"><b>Risks &amp; Challenges</b></p>	<p style="text-align: center;"><b>H</b></p> <p style="text-align: center;"><b>Risks &amp; Challenges</b></p>
<p>You didn't bring your rain gear and got caught in the early-morning fog and rain.</p> <p><b>Lose a turn</b> while you wait for your clothes to dry out.</p>	<p>What do you need to bring with you when you hike in Haleakalā National Park?</p> <ul style="list-style-type: none"><li>a) rain gear and warm clothes</li><li>b) Gameboy and extra batteries</li><li>c) food &amp; water</li><li>d) a and c</li></ul> <p><b>Answer: D</b></p>



The Dating Game Cards (cut on solid lines, fold on dashed lines)

<p style="text-align: center;"><b>H</b></p> <p style="text-align: center;"><b>Risks &amp; Challenges</b></p>	<p style="text-align: center;"><b>H</b></p> <p style="text-align: center;"><b>Risks &amp; Challenges</b></p>
<p>You didn't bring enough water with you.</p> <p><b>Lose a turn</b> while you wait for your hiking companions to share their water with you.</p>	<p>You wore slippers instead of hiking boots and sprained your ankle.</p> <p><b>Lose a turn</b> while you wrap your ankle.</p>
<p style="text-align: center;"><b>H</b></p> <p style="text-align: center;"><b>Risks &amp; Challenges</b></p>	<p style="text-align: center;"><b>H</b></p> <p style="text-align: center;"><b>Risks &amp; Challenges</b></p>
<p>You are drinking plenty of water, which helps keep your body hydrated in the dry, sunny environment.</p> <p><b>Move ahead one space</b> since you're feeling so strong.</p>	<p>You picked up <i>'ōpala</i> (garbage) on the trail.</p> <p><b>Move ahead two spaces</b> for cleaning up after thoughtless visitors.</p>



The Dating Game Cards (cut on solid lines, fold on dashed lines)

<p style="text-align: center;"><b>H</b></p> <p style="text-align: center;"><b>Risks &amp; Challenges</b></p>	<p style="text-align: center;"><b>H</b></p> <p style="text-align: center;"><b>Risks &amp; Challenges</b></p>
<p>You saw another visitor going off the trail and politely asked that person to stay on established and marked trails.</p> <p><b>Move ahead one space</b> for helping to protect the plants and insects that live among the cinders.</p>	<p>You see a <i>nēnē</i> begging. What do you do?</p> <ul style="list-style-type: none"> <li>a) feed it Oreos</li> <li>b) feed it your granola bar</li> <li>c) chase it away</li> <li>d) ignore it</li> </ul> <p><b>Answer</b> D (You shouldn't chase a <i>nēnē</i> since it is an endangered species and it may feel threatened and try to attack you.)</p>
<p style="text-align: center;"><b>H</b></p> <p style="text-align: center;"><b>Risks &amp; Challenges</b></p>	<p style="text-align: center;"><b>H</b></p> <p style="text-align: center;"><b>Risks &amp; Challenges</b></p>
<p>You see another visitor feeding a <i>nēnē</i>. What do you do?</p> <ul style="list-style-type: none"> <li>a) join in</li> <li>b) push the other person out of the way so you can feed the <i>nēnē</i></li> <li>c) ask the other visitor not to feed the <i>nēnē</i></li> <li>d) tell the person to feed the chukars instead</li> </ul> <p><b>Answer: C</b></p>	<p>You see two other students going off trail and making designs in the cinder. What do you do?</p> <ul style="list-style-type: none"> <li>a) help them because you are a better artist than they are</li> <li>b) ask them to come on trail as the design won't go away for many years</li> <li>c) ignore them</li> <li>d) make your own design somewhere else</li> </ul> <p><b>Answer: B</b></p>



The Dating Game Cards (cut on solid lines, fold on dashed lines)

<p style="text-align: center;"><b>H</b></p> <p style="text-align: center;"><b>Risks &amp; Challenges</b></p>	<p style="text-align: center;"><b>n</b></p> <p style="text-align: center;"><b>Double Jeopardy</b></p>
<p>Why do you need to stay on trails in Haleakalā National Park?</p> <p>a) there are endangered species that you could accidentally crush b) just because c) because the park ranger told you to d) so you don't get lost</p> <p><b>Answer:</b> A</p>	<p>How many spaces are you willing to risk? 2? 4? 6?</p> <p>Which two stages of volcanic activity are the most likely for Haleakalā to be in currently?</p> <p><b>Answer:</b> Alkalic capping and renewed volcanism (or rejuvenation) stages</p>
<p style="text-align: center;"><b>n</b></p> <p style="text-align: center;"><b>Double Jeopardy</b></p>	<p style="text-align: center;"><b>n</b></p> <p style="text-align: center;"><b>Double Jeopardy</b></p>
<p>How many spaces are you willing to risk? 2? 4? 6?</p> <p>How tall does Haleakalā stand above sea level today?</p> <p><b>Answer:</b> 3056 meters (10,023 feet)</p>	<p>How many spaces are you willing to risk? 2? 4? 6?</p> <p>How old is Haleakalā Volcano?</p> <p>a) 1.7 million years b) 0.7 million years c) 1 million years d) none of the above</p> <p><b>Answer:</b> 1.7 million years</p>





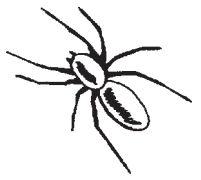
The Dating Game Cards (cut on solid lines, fold on dashed lines)

<p style="text-align: center;">n</p> <p style="text-align: center;"><b>Double Jeopardy</b></p>	<p style="text-align: center;">n</p> <p style="text-align: center;"><b>Double Jeopardy</b></p>
<p>How many spaces are you willing to risk? 2? 4? 6?</p> <p>On average, how frequently has Haleakalā erupted?</p> <p><b>Answer:</b> Every 200-500 years</p>	<p>How many spaces are you willing to risk? 2? 4? 6?</p> <p>What are vesicles?</p> <p><b>Answer:</b> Holes in the lava from when the lava cooled quickly and trapped gases</p>
<p style="text-align: center;">n</p> <p style="text-align: center;"><b>Double Jeopardy</b></p>	<p style="text-align: center;">n</p> <p style="text-align: center;"><b>Double Jeopardy</b></p>
<p>How many spaces are you willing to risk? 2? 4? 6?</p> <p>What does pyroclastic mean?</p> <p><b>Answer:</b> Fire-broken</p>	<p>How many spaces are you willing to risk? 2? 4? 6?</p> <p>What are the two types of lava flows?</p> <p><b>Answer:</b> 'A'ā and pāhoehoe</p>



The Dating Game Cards (cut on solid lines, fold on dashed lines)

<p style="text-align: center;"><b>Connector Trails</b></p>	<p style="text-align: center;"><b>Connector Trails</b></p>
<p><b>Question</b> True or False? Based on past patterns of eruption, Haleakalā is not expected to erupt again for another 50,000 years.</p> <p><b>Answer</b> False</p>	<p><b>Question</b> True or False? The basin at the summit of Haleakalā was caused by a huge explosion which blew the top of Haleakalā off.</p> <p><b>Answer</b> False</p>
<p style="text-align: center;"><b>Connector Trails</b></p>	<p style="text-align: center;"><b>Connector Trails</b></p>
<p><b>Question</b> True or False? Hawaiian volcanoes tend to have very explosive eruptions compared to other types of volcanoes around the world.</p> <p><b>Answer</b> False</p>	<p><b>Question</b> What is an isotope?</p> <p><b>Answer</b> An atom of an element that has a different number of neutrons than other atoms of the same element.</p>



The Dating Game Cards (cut on solid lines, fold on dashed lines)

<p style="text-align: center;"><b>Connector Trails</b></p>	<p style="text-align: center;"><b>Connector Trails</b></p>
<p><b>Question</b> True or false? Chemical analyses have found many differences between rocks from the Kula Volcanics series and the Hāna formation.</p> <p><b>Answer</b> False</p>	<p><b>Question</b> What percentage of the total volume of Haleakalā stands above sea level?</p> <p><b>Answer</b> 5 percent</p>
<p style="text-align: center;"><b>Connector Trails</b></p>	<p style="text-align: center;"><b>Connector Trails</b></p>
<p><b>Question</b> True or false? Dave Sherrod believes there were glaciers on the summit of Haleakalā during the last ice age.</p> <p><b>Answer</b> False</p>	<p><b>Question</b> When did Haleakalā last erupt?</p> <p><b>Answer</b> About 1790 (although this answer is debatable since recent evidence suggests these flows may be about 400 years old)</p>



Alpine/Aeolian Unit 2

# Summer Every Day and Winter Every Night

## Overview

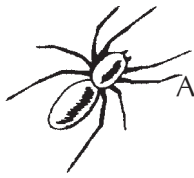
The summit of Haleakalā is a place of extremes where the descriptive phrase “summer every day and winter every night” may be applied. Climate is a primary determinant of the environmental conditions in which the plants and animals of the alpine/aeolian zone live. This unit helps students explore the climate of this region and take from that exploration a working understanding of many of the environmental conditions to which alpine/aeolian residents are adapted. These conditions include wind, dramatic temperature fluctuations between day and night, intense sun exposure, freezing temperatures, and little moisture.

## Length of Entire Unit

Three 50-minute periods

## Unit Focus Questions

- 1) What factors influence the climate in the alpine/aeolian ecosystem?
- 2) What are the environmental conditions in the alpine/aeolian ecosystem?



## Unit at a Glance

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### Activity #1

---

#### What's the Temperature at the Summit?

Students predict the temperature at the summit of Haleakalā based on the current temperature at their school, and discuss possible explanations for differences between their calculations and the actual temperature.

#### Length

One-half class period

#### Prerequisite Activity

None

#### Objectives

- Define adiabatic lapse rate.
- Calculate the summit temperature using the adiabatic lapse rate.
- Discuss discrepancies between student calculations and the actual temperature.

#### DOE Grades 9-12 Science Standards and Benchmarks

DOING SCIENTIFIC INQUIRY: Students demonstrate the skills necessary to engage in scientific inquiry.

- Identify and discuss alternative explanations and conclusions and models.

### Activity #2

---

#### Mauna Lei Mystery

By investigating and learning about the climate conditions that form the *mauna lei*, or the layer of clouds that often rings Haleakalā, students learn about the environmental conditions of the alpine/aeolian ecosystem.

#### Length

Two class periods

#### Prerequisite Activity

None

#### Objectives

- Read and interpret data from tables and graphs.
- Compare climatic conditions at several elevations on leeward Haleakalā, including the summit area.
- Find evidence for the effects of the trade-wind air-temperature inversion in basic climatic data.
- Explain the formation of the layer of clouds that regularly rings the upper slopes of Haleakalā.

#### DOE Grades 9-12 Science Standards and Benchmarks

DOING SCIENTIFIC INQUIRY: Students demonstrate the skills necessary to engage in scientific inquiry.

- Organize, analyze, validate and display data/information in ways appropriate to scientific investigations, using technology and mathematics.
- Formulate scientific explanations and conclusions and models using logic and evidence.
- Communicate and defend scientific explanations and conclusions.



### Activity #3

## Summer Every Day and Winter Every Night?

Students analyze temperature information available on the Internet to draw conclusions about the applicability of the statement “summer every day and winter every night” to the alpine/aeolian ecosystem.

### Length

Optional class discussion, partial period; otherwise, homework only

### Prerequisite Activity

None

Works best in conjunction with Activity #1

“What’s the Temperature at the Summit?” or

Activity #2 “*Mauna Lei* Mystery,” rather than as a stand-alone activity.

### Objectives

- Locate and interpret temperature data from the Internet.
- Gather evidence that supports or refutes the description of tropical alpine environments: “summer every day and winter every night.”

### DOE Grades 9-12 Science Standards and Benchmarks

DOING SCIENTIFIC INQUIRY: Students demonstrate the skills necessary to engage in scientific inquiry.

- Communicate and defend scientific explanations and conclusions.

## Enrichment Ideas

- Use information available on the Western Regional Climate Center website at <koa.ifa.hawaii.edu> (which gives daily and archived weather) to research other weather and climate-related questions about Haleakalā.
- Based on their work in this unit, especially the presentations in Activity #2 “*Mauna Lei* Mystery,” have students create educational displays about why the *mauna lei* forms around Haleakalā, or more generally, about the climate of the upper slopes of the mountain. Display these in the school cafeteria or another prominent location.

## Resources for Further Reading and Research

Minyard, W. P., T. W. Giambelluca and D. Nullet, *Elevational Patterns of Climate on the Leeward Slope of East Maui, Hawaii*, Cooperative National Park Resources Studies Unit, University of Hawai‘i at Manoa, 1994.

*You may request a copy of this report from the Pacific Cooperative Studies Unit, University of Hawai‘i, 3190 Maile Way, St. John 410, Honolulu, HI 96822.*

Nullet, D. and M. Sanderson, “Radiation and Energy Balances and Air Temperature,” in M. Sanderson (ed.), *Prevailing Trade Winds: Weather and Climate in Hawai‘i*, University of Hawai‘i Press, 1993.

Schroeder, T., “Climate Controls,” in M. Sanderson (ed.), *Prevailing Trade Winds: Weather and Climate in Hawai‘i*, University of Hawai‘i Press, 1993.





Activity #1

# What's the Temperature at the Summit?

## ● ● ● In Advance *Determine Your School's Elevation*

- Determine the approximate elevation of your school by looking on a topographic map. You or a student may use the map on page 21 of *Atlas of Hawaii*, 2nd ed. (University of Hawai'i Press, 1983). For a more accurate determination, check a topographic map in an outdoor store or use an altimeter.

## ● ● ● Class Period One *Temperature Calculations*

### Materials & Setup

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*For the class*

- Outdoor thermometer
- Access to the Internet

### Instructions

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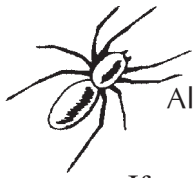
- 1) Begin a discussion about the summit area of Haleakalā by asking students to think of questions they have about the top of the mountain. Students can be broken into small discussion groups to think about this for a few minutes, or this question can go to the class as a whole. (Instead of questions, you could have students list what comes to mind when they think about the top of the mountain.)

Write the questions or observations on the board. Ask which relate to climate factors such as air temperature, rain, or wind.

Ask students who have been to the top of Haleakalā to talk about the climate in the summit area. If you get comments such as “cold” or “windy,” that is a great starting point. But encourage students to think in more detail. What time of year were they at the summit? What time of day? Were the skies clear or cloudy? Do they remember driving through a layer of clouds or seeing clouds below them? Have they ever seen snow at the top?

- 2) Ask students to guess what the weather is currently like near the top of Haleakalā and to explain their reasoning. If you can look out at the mountain, do so.
- 3) Have students calculate an estimated temperature for the summit using the *adiabatic lapse rate*. Adiabatic lapse rate refers to how quickly an air mass cools or heats simply due to rising or sinking. Air temperature decreases with increasing elevation by approximately 3° F per 305 meters (1000 feet).





If students need help making this calculation, here are the steps:

- a) Determine the elevation of the school. Calculate the difference in elevation between the school and the summit, 3056 meters (10,023 feet).
  - b) For each 305 meters (1000 feet) of elevation rise, the normal adiabatic lapse rate is approximately -3 degrees F. Therefore:  
$$(\text{Difference in elevation}/305) \times -3^\circ = \text{Difference in temperature}$$
  - c) Add the negative temperature difference to the temperature at the school to get the estimated temperature at the summit.
- 4) Use the Internet to check the temperature at the summit. The URL is <[koa.ifa.hawaii.edu/Weather/current.html](http://koa.ifa.hawaii.edu/Weather/current.html)>.
- 5) If there is a difference between their calculated temperature and the actual temperature at the summit, ask students to speculate about what might account for the discrepancy. Here are a few ideas to explore:
- a) Moisture content of the air mass. Dry air changes temperature at a rate of approximately 5.4° F per 305 meters (1000 feet). But an air mass saturated with water vapor cools more slowly than a drier air mass. This is because moisture condenses as the air mass rises, releasing heat and slowing the cooling rate. This “moist adiabatic lapse rate” varies greatly. As the air mass rises, cools, and loses moisture, the lapse rate increases and approaches the dry adiabatic lapse rate.
  - b) Location on the island. If your school is on West Maui, your calculations for Haleakalā may not be accurate because the temperature at your elevation may be significantly different than it would be if you were making these calculations from the flanks of Haleakalā.
  - c) Temperature inversion. When trade winds are consistent, there is often a pronounced “temperature inversion” in the atmosphere around Haleakalā. This is an area where the air mass on top is warmer than that underneath. This “upside down” air temperature pattern may interfere with normal lapse rates. Students explore this phenomenon more fully in Activity #2: “*Mauna Lei* Mystery.”



Activity #2

# Mauna Lei Mystery

## ● ● ● Class Period One *Solving the Mystery*

### Materials & Setup

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- *He Lei Keakea* acetate (master, p. 11)
- Overhead projector and screen

For each group of four to six students

- Student Page “Solving the *Mauna Lei* Mystery” (pp.17-25)

### Instructions

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- 1) Show the *He Lei Keakea* acetate to the class and read the Hawaiian chant, or have one or all the students read it. Then read the English translation and ask students whether they have ever noticed this *lei* of clouds around Haleakalā. What do they think causes it?
- 2) Divide the class into groups of four to six and pass out the Student Page “Solving the *Mauna Lei* Mystery.” Allow groups to work together to explain the regular formation of the “cloud lei” around the upper slopes of Haleakalā, using the clues provided.

### Teaching Option

If you prefer that your students work with graphs instead of data tables, substitute the four graphs and one table in the “Optional Graphs for Solving the *Mauna Lei* Mystery” (master, pp. 12-16) for data tables 1-5 in the Student Page “Solving the *Mauna Lei* Mystery.” Have students use these graphs instead of the tables to fill in the Climate Conditions Clues Summary Table (p. 18).

- 3) If students are having difficulty working through the clues, you may want to prompt them with questions. For the Climate Conditions Clues (pp. 18-21), these questions may be helpful:
  - a) Looking at the grid, how would you characterize the climate at each of the five elevations?
  - b) Which of the climatic conditions do not change in a linear fashion according to the elevations?  
What do you think might explain unexpected changes in conditions at the middle elevations?

For the Global Forces Clues (pp. 22-24), these questions may help:

- a) What happens to moisture in the air as the air cools or is under less pressure?
- b) It’s generally true that “hot air rises,” but is there any evidence that a warmer air mass may be found on top of cooler air in the atmosphere?
- c) What effect would a layer of warmer air over cooler air have on cloud formation?



## ● ● ● Class Period Two Team Presentations

### Instructions

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- 1) Group by group, have students present their findings to the class, explaining how they resolved the *mauna lei* mystery and what evidence and reasoning they used to support their conclusions. Either have each group present its answers to all the questions posed on the student sheet, or ask different groups to cover each question in turn.
- 2) Culminate the discussion by asking the final question posed on the student page, “What are the main climatic conditions and patterns within the alpine/aeolian zone?” Ask students to consider what living conditions are like for plants and animals that live in the alpine/aeolian zone, and to compare them to likely conditions on other parts of Haleakalā.

### Journal Ideas

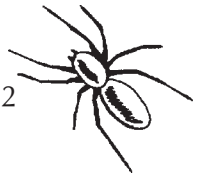
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- There is a weather phenomenon known as a Kona storm that occasionally occurs in the Hawaiian Islands. These spectacular winter storms are associated with strong winds from the south that bring large amounts of rain. When Kona storms hit Haleakalā, maximum rainfall generally falls at the summit, and rainfall decreases with elevation. Where do you find evidence of Kona storms on Table 5 of the Student Page “Solving the *Mauna Lei* Mystery”? Explain your answer and hypothesize about how a strong season of Kona storms might skew other climate data you have been working with in this activity.
- In addition to the *mauna lei*, what other weather phenomena can you think of that seem to have regular daily patterns of change?
- Ancient Hawaiians did not live in the summit area of Haleakalā, which is a sacred place in Hawaiian tradition. What would it have been like for early Hawaiians to visit the summit area? How might they have protected themselves from climate extremes without modern technology?

### Assessment Tools

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- Student Page “Solving the *Mauna Lei* Mystery” (teacher version, pp. 9-10)
- Cooperation and participation in group work
- Team presentations: Evaluate on the basis of reasoning, clarity, and accuracy of the presentation, and completeness.
- Journal entries



Teacher Version

## Solving the *Mauna Lei* Mystery

[This teacher version contains only the portions of the student page that require student responses.]

1) At what time of day and approximate elevation does the *mauna lei* usually appear and disappear?

- On leeward Haleakalā, the *mauna lei* generally appears on the following cycle: 7:00 a.m., clear skies; by 10:00 a.m., cloud begin to form; 3:00 p.m., a band of clouds obscures the view of the summit; by 6:00 p.m., clouds have dissipated, as the intensity of solar radiation decreases and the temperature and pressure gradients shift again. (Students will not be able to figure the exact times based on the information provided in the student page, but they should be able to reason their way to the general pattern.)

- Using the Climate Clues Summary Table, students should reason that the *mauna lei* occurs in the middle elevations above 1650 meters (5412 feet), more likely higher up around 2130 meters (6986 feet) or even higher. In the “Solar Radiation” and “Rainfall” columns, students see that the relationship between these variables and elevation is not linear, suggesting the presence of cloud cover. The drop in solar radiation at the 1650-meter (5412 feet) level suggests shading by cloud cover, and increased rainfall at the 2130-meter (6986 feet) station suggests that this station may be just below the usual lower limit of the *mauna lei*. The width of the cloud formation is not apparent from the clues that students have been provided.

2) What are the climate conditions above and below the *mauna lei*?

- Above the *mauna lei*: coldest, driest air, greatest wind speed, greatest solar radiation, low rainfall

- Below the *mauna lei*: warm temperatures, high relative humidity, low solar radiation, rainier than above the *mauna lei*

3) Why doesn't the *mauna lei* form higher on the mountain, around the summit?

- Cloud formation is capped by the trade wind inversion. When rising and cooling clouds meet warm descending air in the Hadley Cell, the inversion layer forms. Warm air overlying the cooler air is a barrier to clouds—clouds forced through the inversion layer rapidly evaporate in the dry air above it. From the Climate Clues Summary Table, students should surmise that this inversion layer typically occurs between 2130 meters (6986 feet) and 2600 meters (8528 feet). (The trade wind temperature inversion occurs at altitudes between 1525 meters (5000 feet) and 3050 meters (10,000 feet). Students are not given enough information to determine this range.)



- 4) What global factors are involved in the formation of the *mauna lei*? Explain.
- Global air circulation patterns including the Hadley Cell cause the inversion layer, and in combination with the Coriolis effect give rise to the trade winds themselves. (See the Student Page “Solving the *Mauna Lei* Mystery” for more details.)
- 5) What are the different causes of the *mauna lei* on the leeward vs. the windward side of Haleakalā? Explain the effects of temperature and pressure on the formation of the *mauna lei* on windward and leeward Haleakalā.
- On the windward side, the *mauna lei* is formed when moist trade winds are blown up the slopes of Haleakalā. As the air rises, temperature and air pressure drop, and the moisture in the air condenses to form clouds.
  - On the leeward side, the sun heats the slopes of Haleakalā and the surrounding air. This creates a zone of warmer air at higher elevations where solar radiation is more intense. As air over the heating slopes rises, this creates a pressure differential that draws air from over the ocean up the mountain’s slopes. This moister air cools as it is forced upward, forming a layer of clouds.
- 6) What are the main climatic conditions and patterns within the alpine/aeolian zone?
- Dry air and little rain, hot during the day, clear skies, sunny, windy.

**Climate Conditions Clues Summary Table**

Elevation	Air Temperature	Relative Humidity	Wind Speed	Solar Radiation	Rainfall
950 m (3116 ft)	5	5	1	2	4
1650 m (5412 ft)	4	4	2	1	3
2130 m (6986 ft)	3	3	3	3	5
2600 m (8528 ft)	2	2	4	4	2
3000 m (9840 ft)	1	1	5	5	1

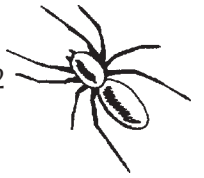


Photo: Ann Fielding

## He Lei Keakea

*He lei keakea noho mai la i ka mauna  
Ka mauna ki'eki'e i luna kū kilakila  
Kilakila nō luna  
Nō luna i ke ao  
Ke ao ua malu nā kumu la'au  
La'au ho'ohu'ohu  
'Ohu'ohu ho'ohiehie  
Ho'ohiehie launa 'ole!  
'A'okle lua na'e ke 'ike aku  
He'ike aku nā moku 'o Hawai'i  
Hawai'i ke kuine 'o ka Pākipika  
Ka Pākipika ua la'i i ka lā  
Ka lā ho'olewa i ka nalu  
Ka nalu kohu lei ana  
Lei ana i ke aloha  
Pumehana me ke aloha  
Aloha e!  
— From Winona Desha Beamer, Talking  
Story With Nona Beamer, *The Bess Press*,  
Honolulu, 1984.*

## The White Lei

The soft white lei encircles the crest of the  
mountain  
The mountain high above standing in great  
majesty  
Majestic on high,  
Bedded in clouds.  
The clouds cast a shadow on the trees  
The trees so haughty;  
So haughty and proud,  
This is splendor beyond compare!  
There is no beauty to equal this sight  
The sight of the islands of Hawai'i  
Hawai'i, the Queen of the Pacific.  
The Pacific lies calm in the sun  
The sun, moving on the waves  
The waves bedeck, as a lei  
A lei of love,  
Warm is this love,  
It is love, indeed!



## Optional Graphs for Solving the *Mauna Lei* Mystery

You may substitute the four graphs and one table contained in this resource section for the five tables provided in the Student Page “Solving the *Mauna Lei* Mystery.” You may put the graphs up on the overhead or allow each student or group to work with its own copies. (Note: Because these graphs may be tricky to read, you could have students trace over the data line for each elevation in a different color pen or pencil. You could do the same on your overhead.)

Graphics and all data in the tables below are taken from Minyard, W. P., T. W. Giambelluca and D. Nullet, *Elevational Patterns of Climate on the Leeward Slope of East Maui, Hawaii*, Cooperative National Park Resources Studies Unit, University of Hawai‘i at Manoa, 1994 (used with permission of the Pacific Cooperative Studies Unit).

Table : Rainfall (mm/day)

	Elevation (m)				
	950	1650	2130	2600	3000
January	3.0	5.6	7.4	4.3	5.5
February	2.3	2.1	4.6	1.9	2.9
March	1.5	3.2	10.0	7.2	6.3
April	0.2	0.7	0.6	0.6	0.6
May	0.4	0.8	1.9	0.8	0.2
June	0.4	0.8	2.2	0.9	0.4
July	0.3	1.1	2.0	1.0	0.9
August	0.5	2.1	4.3	3.2	1.6
September	0.6	3.8	3.5	2.2	2.0
October	0.5	2.3	2.6	2.0	2.0
November	4.2	3.2	5.8	9.5	12.5
December	3.7	3.8	5.2	6.3	7.1
Totals	17.6	29.5	50.1	39.9	42.0
Average	1.47	2.46	4.18	3.33	3.50

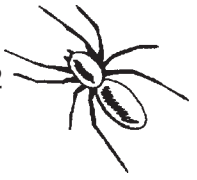
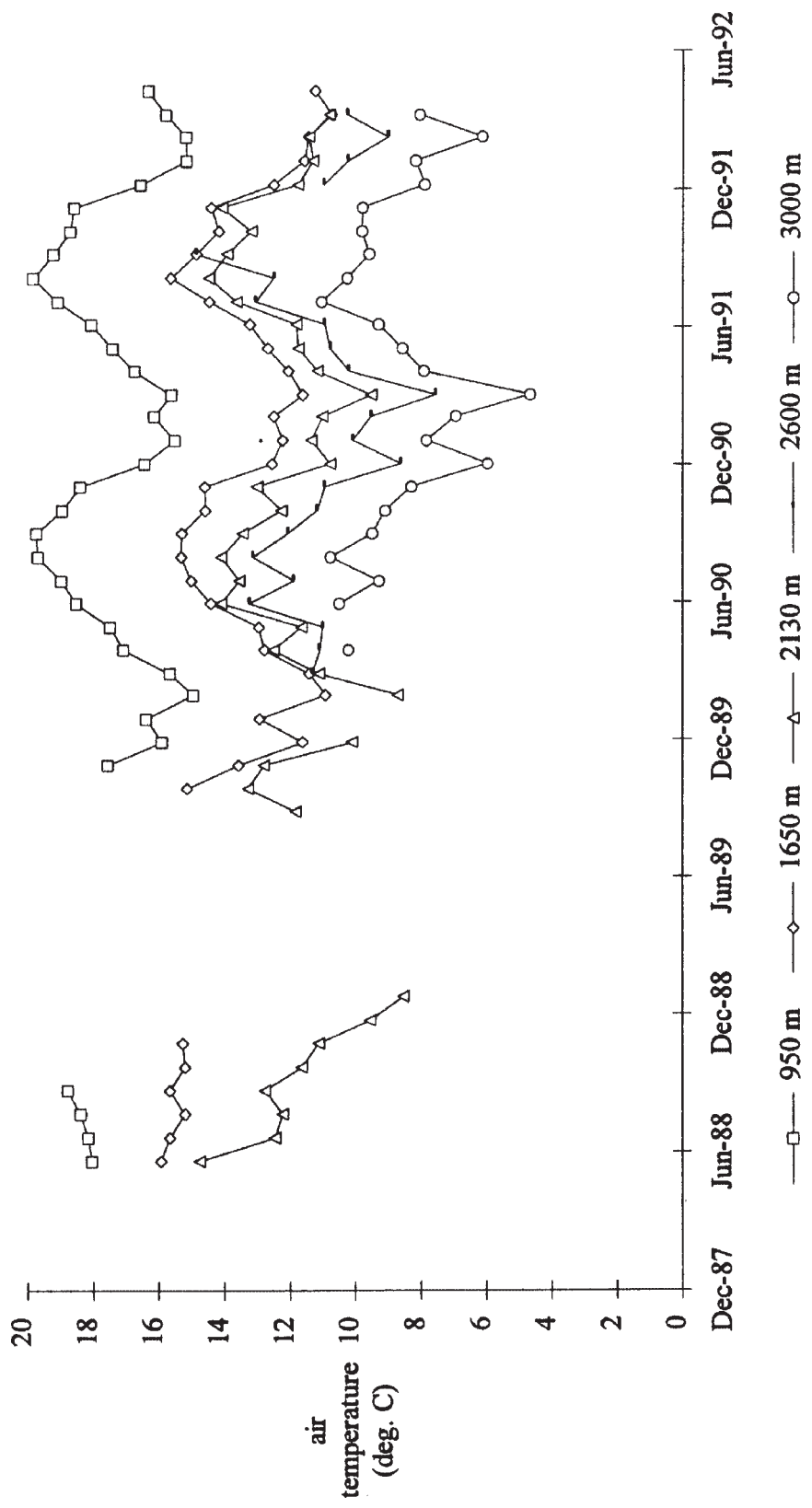


Figure 1: Monthly Mean Air Temperature (° C)





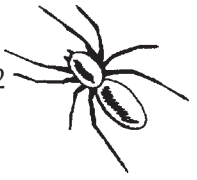
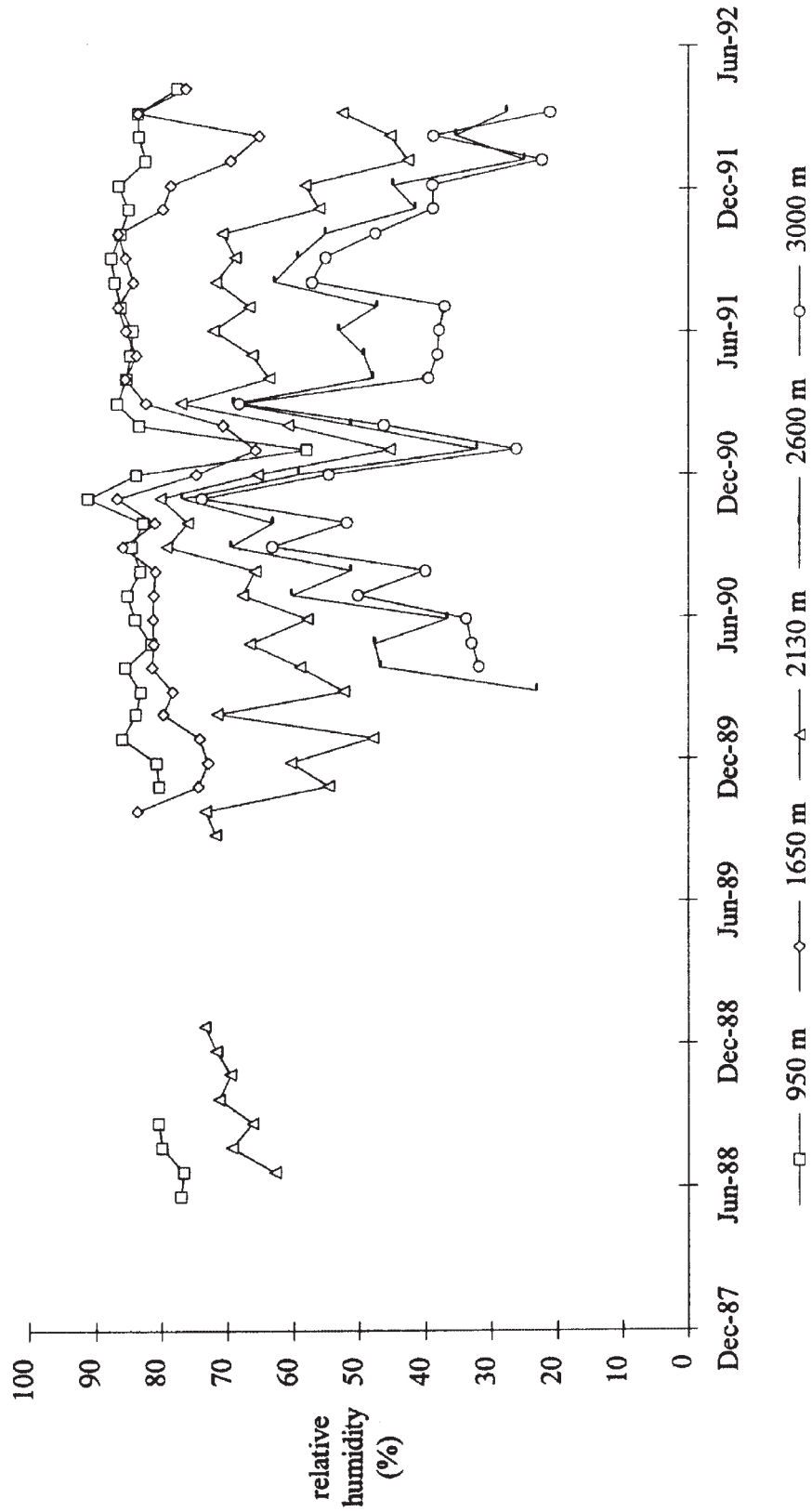


Figure 2: Monthly Mean Relative Humidity



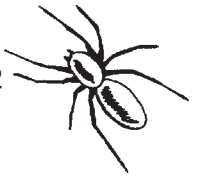


Figure 3: Monthly Mean Wind Speed

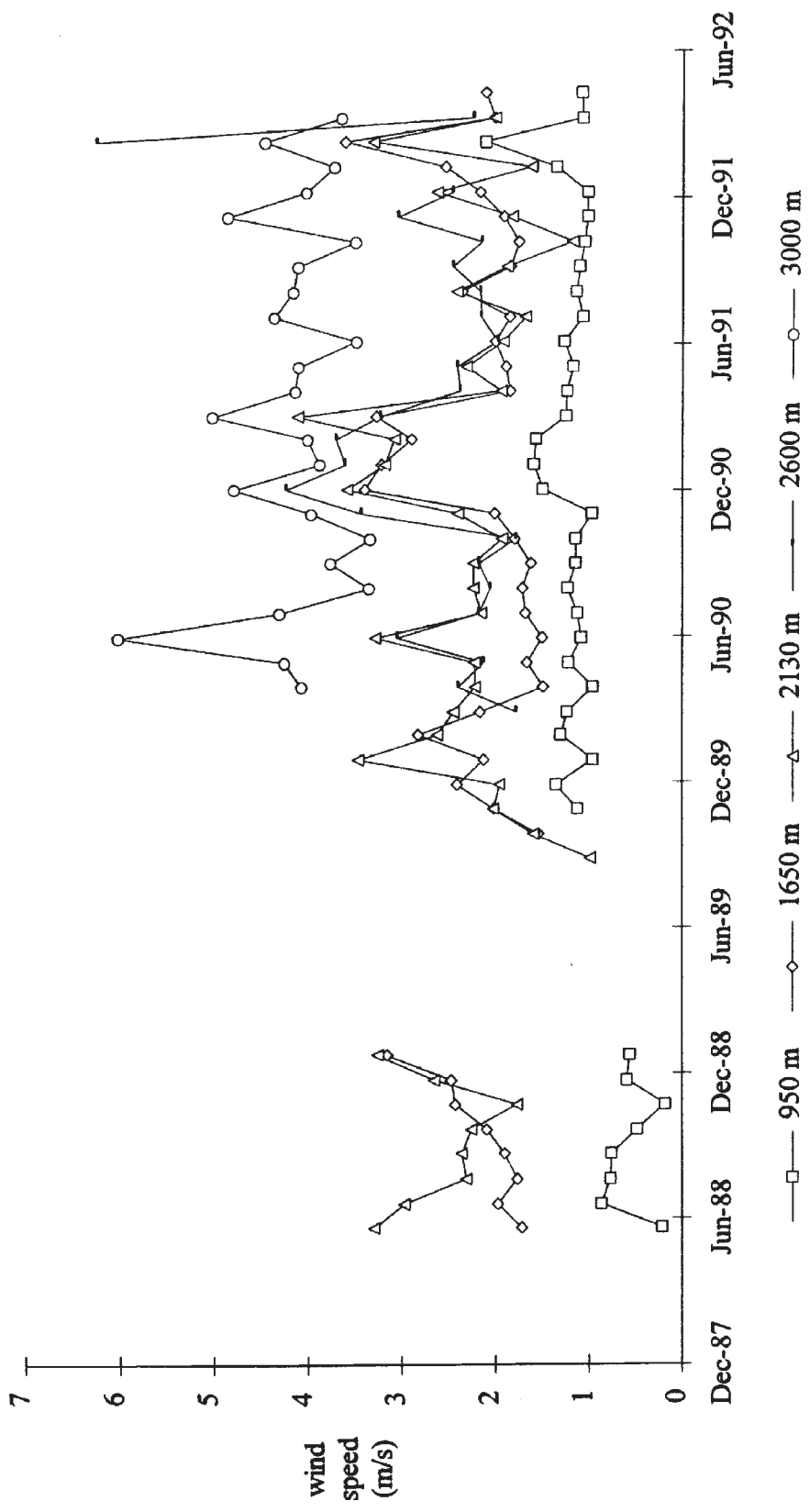
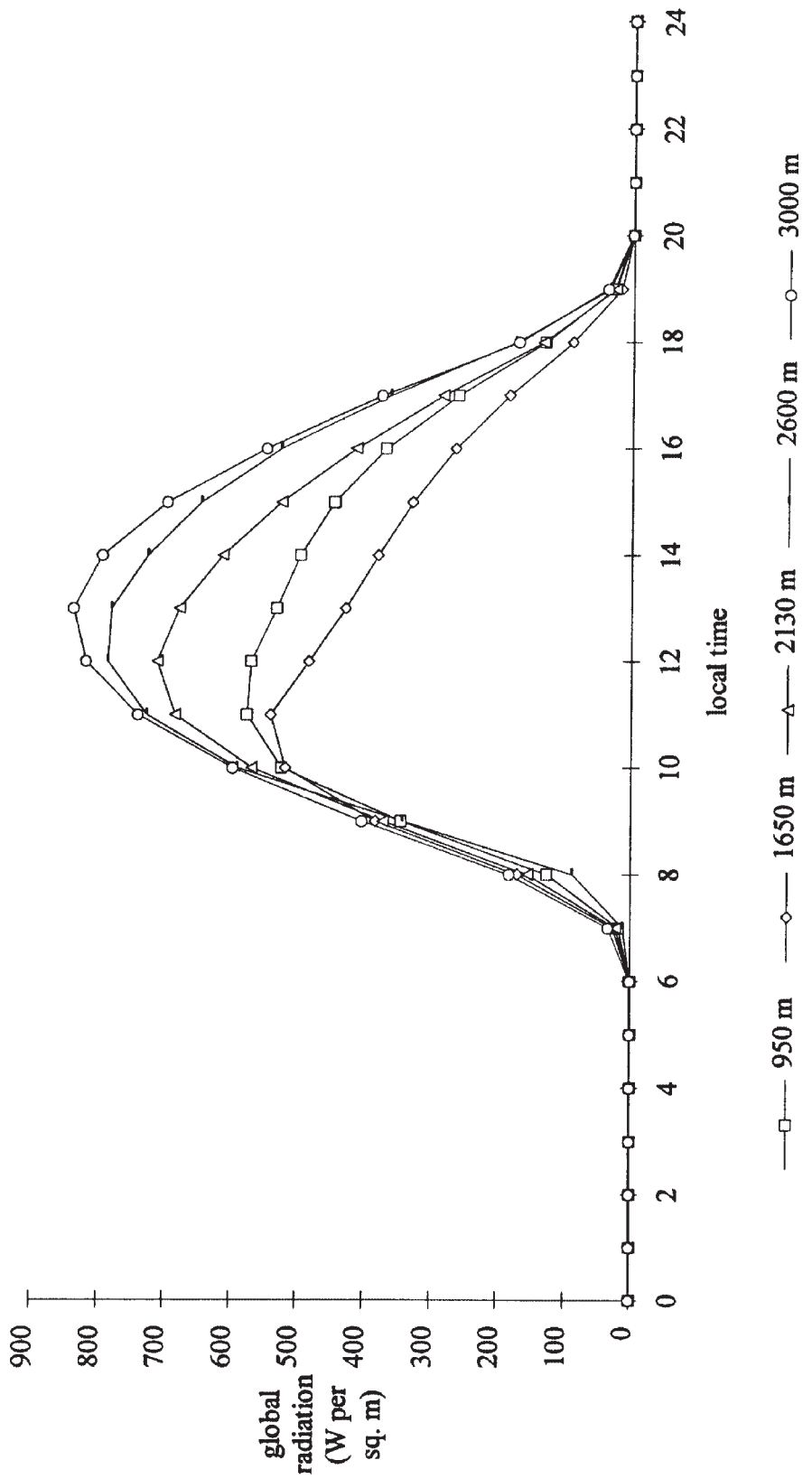
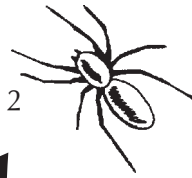




Figure 4: Mean Diurnal Cycle of Global Radiation





# Solving the *Mauna Lei* Mystery

The clouds that form around the slopes of Haleakalā and other tall Hawaiian volcanoes have been called a *mauna lei*, or a “mountain lei.” On most days, at about the same elevation and time, this cloud lei mysteriously appears. Usually by the evening, it is gone. Another term for these clouds is *nāulu*. That name refers to the shaded, moist band created by the clouds, which created an ideal environment for growing breadfruit (*ulu*).

If you stand at the Haleakala National Park Visitor Center and look into the crater you can often see clouds ascending Ko‘olau and Kaupō Gaps . . . . [T]he clouds often disappear as they enter the crater floor. “Two gaps, thousands of feet deep, broke the rim of the crater, and through these Ukiukiu (a Haleakalā wind) vainly strove to drive his fleecy herds of trade-wind clouds. As fast as they advanced through the gaps, the heat of the crater dissipated them into thin air, and though they advanced always, they got nowhere.”

—Jack London, *Cruise of the Snark*, quoted in *Maui: How It Came To Be*, Will Kyselka, University of Hawai‘i Press, Honolulu, 1980, pp. 138-139.

Understanding why the *mauna lei* forms when and where it does can tell you a lot about the climate in the alpine/aeolian zone near the top of Haleakalā. In order to do that, you and your team will become “climate detectives.” Unravel the clues and solve the *mauna lei* mystery.

## Instructions

Use the clue cards provided to answer the following questions:

- 1) At what time of day and approximate elevation does the *mauna lei* usually appear and disappear?
- 2) What are the climate conditions above and below the *mauna lei*?
- 3) Why doesn’t the *mauna lei* form higher on the mountain, around the summit?
- 4) What global factors are involved in the formation of the *mauna lei*? Explain.
- 5) What are the different causes of the *mauna lei* on the leeward vs. the windward side of Haleakalā?  
Explain the effects of temperature and pressure on the formation of the *mauna lei* on windward and leeward Haleakalā.
- 6) What are the main climatic conditions and patterns within the alpine/aeolian zone?

Your team will present its conclusions and the evidence you used to the rest of the class. You may use written summaries, graphic representations, models, or other means of presentation you believe will best present your case to the class.



## Climate Conditions Clues

Use the information presented in Tables 1-5 to fill in the grid below. Follow the instructions below to rank each characteristic of the climate in order using the numbers from 1-5. The patterns you see in the grid will provide clues you can use.

**Air temperature** (Use Table 1.)

Number the elevation zones in order from 1 to 5. 1 = lowest temperature, 5 = highest

**Relative humidity** (Use Table 2.)

Number the elevation zones in order from 1 to 5. 1 = lowest relative humidity, 5 = highest

**Wind speed** (Use Table 3.)

Number the elevation zones in order from 1 to 5. 1 = lowest wind speed, 5 = highest

**Solar radiation** (Use Table 4.)

Number the elevation zones in order from 1 to 5. 1 = lowest radiation level, 5 = highest

**Rainfall** (Use Table 5.)

Number the elevation zones in order from 1 to 5. 1 = lowest rainfall, 5 = highest

## Climate Conditions Clues Summary Table

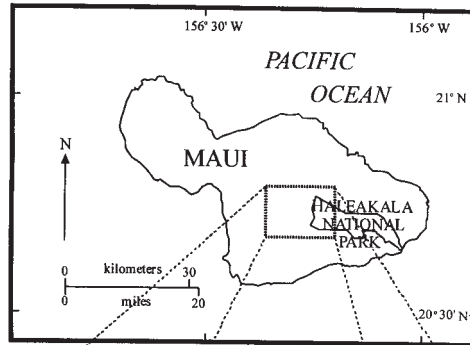
Elevation	Air Temperature	Relative Humidity	Wind Speed	Solar Radiation	Rainfall
950 m (3116 ft)					
1650 m (5412 ft)					
2130 m (6986 ft)					
2600 m (8528 ft)					
3000 m (9840 ft)					



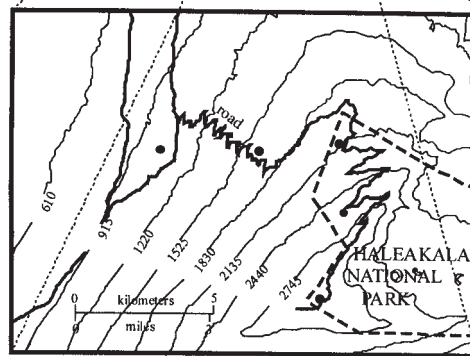
## Climate Conditions Clues

Since about 1990, researchers have been studying the climate at 5 different elevations along Crater Road, in order to quantify (attach numbers to or measure) the climate instead of generalizing about it. In other words, they wanted to be able to say *how* windy it is, *how* rainy or dry, *how* hot or cold. And they wanted to be able to track those changes throughout the day, as well as from month to month and from year to year.

These researchers set up climate stations at 950 m (3116 ft.), 1650 m (5412 ft.), 2130 m (6986 ft.), 2600 m (8528 ft.), and 3000 m (9840 ft.) on the west (leeward) slope of Haleakalā. These stations recorded continuous hourly data, some of which are presented below. By reading the graphs you will know with more accuracy what the climate is like at the different elevations, including the top of the mountain, in the alpine/aeolian zone.



Map of study area



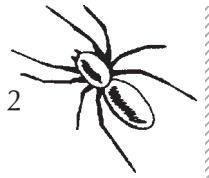
Location of Climate Stations along Crater Road (contour interval in meters)

Graphics and all data in the tables below are taken from:

Minyard, W. P., T. W. Giambelluca and D. Nullet, *Elevational Patterns of Climate on the Leeward Slope of East Maui, Hawaii*, Cooperative National Park Resources Studies Unit, University of Hawai'i at Manoa, 1994 (used with permission of the Pacific Cooperative Studies Unit).

Table 1: Monthly Mean Air Temperature (°C)

	Elevation (m)				
	950	1650	2130	2600	3000
January	15.7	12.3	11.0	10.2	8.1
February	15.5	11.7	10.5	9.3	6.6
March	15.7	11.3	10.5	9.5	6.6
April	16.9	12.4	11.8	10.7	8.3
May	17.5	12.8	11.7	10.9	8.7
June	18.3	14.3	13.3	12.1	9.9
July	18.8	15.0	13.2	12.5	10.2
August	19.3	15.4	13.7	12.8	10.5
September	19.5	15.3	13.4	12.6	9.5
October	18.9	14.8	12.7	11.2	9.5
November	18.2	14.4	13.2	11.0	9.0
December	16.3	12.3	10.6	9.4	6.9
Totals	210.6	162.0	145.6	122.8	103.8
Average	17.55	13.50	12.13	10.23	8.65



## Climate Conditions Clues

Table 2: Monthly Mean Relative Humidity (%)

	Elevation (m)				
	950	1650	2130	2600	3000
January	74.9	69.9	47.5	28.7	24.3
February	83.7	72.6	58.9	43.3	42.6
March	84.6	81.5	61.1	42.4	41.9
April	84.9	82.8	61.4	47.4	37.2
May	83.2	82.6	66.5	48.5	35.7
June	82.8	83.4	65.0	47.0	35.9
July	82.7	84.0	66.0	52.8	43.7
August	83.4	82.7	69.0	57.2	48.7
September	85.6	85.7	72.0	64.4	59.2
October	84.8	84.0	72.9	59.2	49.7
November	85.4	80.5	64.3	59.2	56.4
December	83.8	75.5	64.0	52.8	46.8
Totals	999.8	965.2	768.6	602.9	522.1
Average	83.32	80.43	64.05	50.24	43.51

Table 3: Monthly Mean Wind Speed (meters/second)

	Elevation (m)				
	950	1650	2130	2600	3000
January	1.3	2.7	2.8	3.6	3.8
February	1.7	3.1	3.0	4.7	4.2
March	1.2	2.5	2.9	2.5	4.1
April	1.1	1.7	2.1	2.4	4.1
May	1.2	1.8	2.3	2.3	4.2
June	1.0	1.8	2.7	2.5	4.8
July	1.0	1.8	2.3	2.2	4.4
August	1.1	2.0	2.3	2.1	3.8
September	1.0	1.8	2.1	2.3	3.9
October	1.0	1.8	1.7	2.0	3.4
November	0.9	2.0	2.1	3.2	4.4
December	1.1	2.6	2.7	3.4	4.4
Totals	13.6	25.6	29.0	33.2	49.5
Average	1.13	2.13	2.42	2.77	4.13



## Climate Conditions Clues

Table 4: Mean Diurnal Cycle of Global Radiation (watts/square meter)

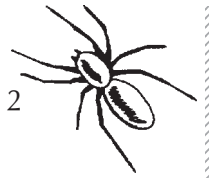
Global radiation is a measure of the solar radiation that reaches the earth. It is the sum of the radiation that reaches the earth from the direction of the sun and the radiation that has been scattered and reflected by the atmosphere.

	Elevation (m)				
	950	1650	2130	2600	3000
January	153.2	144.7	199.6	208.3	214.1
February	170.9	160.5	222.0	217.2	235.0
March	186.5	165.6	231.9	239.0	259.6
April	200.9	163.1	219.0	280.0	315.7
May	221.9	178.8	250.1	295.8	321.8
June	218.1	184.8	278.4	291.5	326.9
July	214.7	174.7	260.4	283.4	309.4
August	208.4	177.8	248.1	292.7	298.9
September	190.0	157.9	206.3	239.3	267.7
October	169.4	143.0	174.4	213.9	236.2
November	141.9	132.5	155.9	177.6	170.9
December	139.9	129.5	155.0	165.8	172.5
Totals	2215.8	1912.9	2601.1	2904.5	3128.7
Average	184.65	159.41	216.76	242.04	260.73

Table 5: Rainfall (mm/day)

	Elevation (m)				
	950	1650	2130	2600	3000
January	3.0	5.6	7.4	4.3	5.5
February	2.3	2.1	4.6	1.9	2.9
March	1.5	3.2	10.0	7.2	6.3
April	0.2	0.7	0.6	0.6	0.6
May	0.4	0.8	1.9	0.8	0.2
June	0.4	0.8	2.2	0.9	0.4
July	0.3	1.1	2.0	1.0	0.9
August	0.5	2.1	4.3	3.2	1.6
September	0.6	3.8	3.5	2.2	2.0
October	0.5	2.3	2.6	2.0	2.0
November	4.2	3.2	5.8	9.5	12.5
December	3.7	3.8	5.2	6.3	7.1
Totals	17.6	29.5	50.1	39.9	42.0
Average	1.47	2.46	4.18	3.33	3.50





## Global Forces Clues

For much of the year, the winds on Maui are predominantly “trade winds,” which blow from the northeast. The trade winds and a phenomenon called the “trade wind inversion” are a bit of a mystery in themselves but one that you can solve using these clues.

### Pressure, Altitude, and Temperature

Keeping straight the relationships among pressure, altitude, and temperature helps when you are trying to understand the trade wind inversion. Here is a quick review:

One way to illustrate these relationships is to think about what it takes for humans to survive at high altitudes. Airplanes are pressurized and heated so humans can survive at nine kilometers in altitude (5.6 miles or about 30,000 feet). If an airplane loses air pressure the oxygen masks are released from the ceiling. Jet pilots in fighters wear oxygen masks rather than having pressurized cockpits. People climbing Mt. Everest reach 8848 m (29,028 ft) and most wear oxygen masks and very warm clothes!

A look at this table shows the relationship between altitude and air pressure:

Altitude	Percent Sea-Level Pressure
0 (sea level)	100
5.6 km (3.5 mi)	50
16.2 km (10.0 mi)	10
31.2 km (19.3 mi)	1
79.2 km (49.1 mi)	0.001
100 km (62.0 mi)	0.00003

#### Altitude Correlations

- Increasing altitude = decreasing pressure, and decreasing temperature
- Decreasing altitude = increasing pressure, and increasing temperature



## Global Forces Clues

### Global Air Circulation Patterns

At the equator, air heated by the sun rises up into the troposphere, an atmospheric layer below the stratosphere. In the troposphere, clouds form, massive air currents and disturbances occur, and temperature decreases with increasing altitude. The troposphere is about 16 km (9.92 miles) high at the equator and 9 kilometers (5.58 miles) high over the poles. Since the air is rising up, it leaves behind an area of low pressure at the equator. (See Figure 1: Idealized Hadley Cell.) The rising air and formation of high cumulus clouds produce large amounts of rainfall for equatorial rain forests.

As the air rises it passes through regions of successively lower pressure. It cools at the rate of 10°C for every kilometer it rises.

As the air reaches the “tropopause” — the boundary between the troposphere and the stratosphere, where the drop in temperature with increasing altitude ceases — it stops rising and begins flowing toward the polar region.

As the upper flow moves poleward, it begins to subside between 20 and 35 degrees latitude. This air is relatively dry, as it has released its moisture near the equator. This zone of subsidence is the site of the world’s subtropical deserts (e.g., central Australia and the Sahara and Sonoran deserts). The sinking air warms due to compression. Where it comes back to earth it produces areas of high air pressure which have weak and variable winds. (Tracking the weather around the Hawaiian Islands illustrates this. When the Pacific High is near Hawai‘i the winds tend to be light.)

As it approaches the surface, the air flow splits. Some of it flows towards the subpolar low, while the rest of it flows toward the equatorial low at the equator. The air flows “downhill” or down the pressure gradient from a high pressure area to a low pressure area. This completes the Hadley Cell.

Both winds are deflected by the spinning of the earth. This is called the “Coriolis effect.” This effect forms the westerlies in high latitudes and the trade winds in tropical latitudes.

These high and low pressure areas and wind patterns affect the climate of the entire globe.

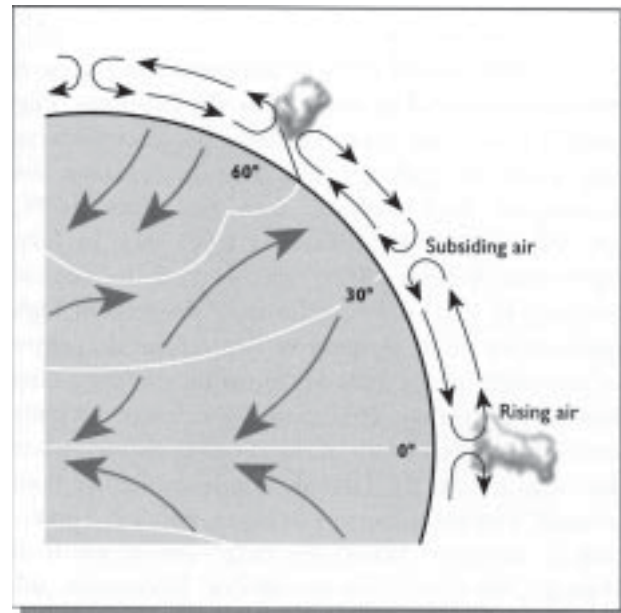


Figure 1: Idealized Hadley Cell, showing vertical and horizontal wind patterns. (From Marie Sanderson, (ed.), *Prevailing Trade Winds*, University of Hawai‘i Press, 1993.)



## Global Forces Clues

### The Trade Wind Inversion

As the trade winds reach Maui they are forced up the mountains on the windward (NE) side. As the wind rises it cools and forms clouds.

There is usually a level on the mountain slopes where the subsiding dry and warming air from the Hadley Cell meets the rising moist and cooling air from the trade winds. This is where the trade wind “inversion” forms. This atmospheric phenomenon is called an inversion because air on top is warmer than the air beneath. Generally speaking, rising air cools at a constant rate (the “lapse rate”). When an inversion is present, however, it interrupts the pattern of consistent rising and cooling.

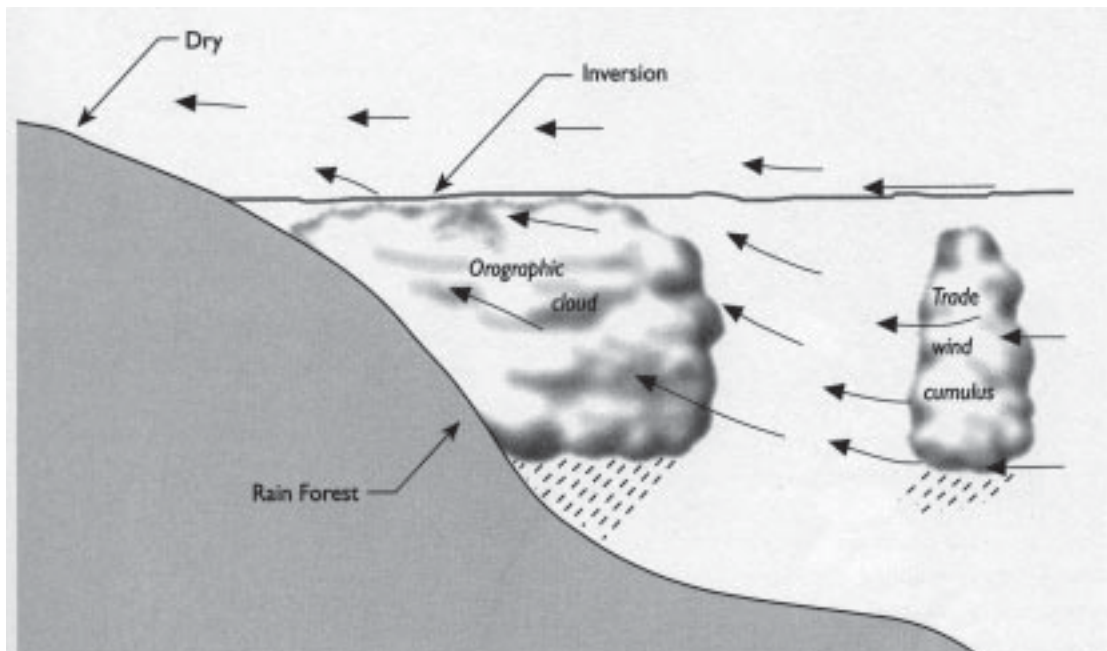


Figure 2: Generalized trade wind weather (From Marie Sanderson, (ed.), *Prevailing Trade Winds*, University of Hawai'i Press, 1993.)



## Global Forces Clues

### Windward Haleakalā

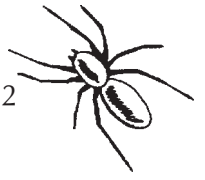
Over the open ocean near Maui, between 56 and 71 centimeters (22-28 inches) of rain falls in an average year. In 1994, a rain gauge placed at 1650 meters (5412 feet) in the rain forest on the windward flank of Haleakalā measured more than 14 meters (45.92 feet or 551 inches) of rainfall *in one year!*

One factor that accounts for this difference is Haleakalā itself. Trade winds blowing across the ocean from the northeast hit the mountain broadside and are forced upward. Some of the wind is deflected to the sides, flowing around the mountain. But much of the moist air is forced up the mountain's steep slopes in a phenomenon known as "orographic lifting", a term that is taken from "orography," a branch of physical geography having to do with mountains.

### Leeward Haleakalā

During the day, solar radiation heats the ground surface and air, creating a zone of warmer air at the higher elevations where solar radiation is more intense.

As the leeward slopes and summit of Haleakalā heat up and the warm air over them rises, moist air is pulled from over the ocean up the mountain's slopes. This moister air cools as it is forced upward.





Activity #3

# Summer Every Day and Winter Every Night?

## ● ● ● In Advance *Student Assignment*

- Assign the Student Page “Is it REALLY Summer Every Day and Winter Every Night?” (pp. 30-31) as homework. (See Class Period One Materials and Setup for details.)

## ● ● ● Class Period One *Optional Class Discussion*

### Materials & Setup \_\_\_\_\_

*For each student*

- Student Page “Is It Really Summer Every Day and Winter Every Night?” (pp. 30-31)
- This homework assignment involves downloading information from the Internet. If you would prefer providing the tables and graphs rather than requiring students to download them, do this ahead of time and make one copy per student.

### Instructions \_\_\_\_\_

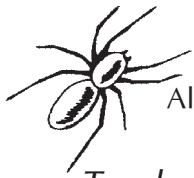
- 1) Discuss student responses to the questions on the student page. Ask students to speculate about how plants and animals might be adapted for living in an environment marked by such dramatic daytime and nighttime temperature differences.

### Journal Ideas \_\_\_\_\_

- Write a one-page entry that describes what you think environmental conditions are like in the alpine/aeolian ecosystem, based on what you have learned so far.
- Have you been to the summit of Haleakalā or another extreme climate? What was it like there? How do people protect themselves against the extremes?
- Imagine what it would be like to be a plant or animal in the alpine/aeolian zone. One researcher said it would be like standing out in a cinder field all day long with no hat and no sunscreen. Then night falls and you have no jacket, but you can’t move. What kinds of analogies would you come up with? Write or draw or make up a chant or a song about living in the alpine/aeolian zone.

### Assessment Tools \_\_\_\_\_

- Class participation
- Student Page “Is It Really Summer Every Day and Winter Every Night?” (teacher version, pp. 28-29)
- Journal entries



Teacher Version

## Is It REALLY Summer Every Day and Winter Every Night?

The high mountains of Hawai‘i have what is called a tropical alpine environment. High mountains in other countries within the tropics, such as Peru, New Guinea, and Venezuela, have some things in common with the Hawaiian Islands. One of the interesting similarities is there is a greater temperature change between day and night than there is between summer and winter. This means that the plants and animals living here are adapted to extreme daily fluctuations.

This feature led one scientist to say that in these environments, it is “summer every day and winter every night.” But you shouldn’t take his word for it. See for yourself!

### Instructions

Find out if day-night temperature differences really are greater than summer-winter temperature differences on the upper slopes of Haleakalā.

- 1) Download your data from the Western Regional Climate Center at <<http://www.wrcc.dri.edu/>>.
  - Select “Western U.S. Climate Historical Summaries.” Scroll down to the colored map and select Hawai‘i.
  - Select “Haleakalā Ranger Station.”
  - Click on the table on the right side, “Period of Record Monthly Climate Summary” and print it.
  - Scroll down the left side, find “Period of Record General Climate Summary Tables” and select “Temperature.” Click on the table and print it.
  - To see the extreme temperatures in chart form, select “Daily Extremes and Averages.” Click on the graph and print it.
- 2) Using the Monthly Climate Summary, find the annual average maximum and minimum temperatures on the far right side of the page. Circle those numbers on the table.

What is the difference between these temperatures? 18.1° F

*This gives you the difference between the average day and night temperatures.*

- 3) Using the same table, look at “Average Max. Temperature” and find the highest and lowest numbers. Circle those numbers on the table.

In which month is the highest average maximum temperature? August

In which month is the lowest average maximum temperature? February

What is the difference between these two numbers? 14.7° F

*This gives you the difference in the daytime temperatures between winter and summer.*



- 4) Do you think it is fair to say that at the upper elevations of Haleakalā, it is “summer every day and winter every night”? Why or why not?

Taking an overall view based on the above information, the answer would be “yes.” The day-night temperature differences are greater than the summer-winter differences. Students may, however, look for additional sources of information to analyze such as diurnal cycles of temperature during different months to come up with a more in-depth answer.

- 5) The climate summary information you are using from the Internet is based on readings from a station at approximately 2134 meters (7000 feet). How would you expect day-night temperature differences in the summit area (where the alpine/aeolian zone is located) to compare to temperatures from a lower elevation? Explain your answer.

Well-reasoned answers are acceptable. Answers are likely to predict greater temperature variations because of increased solar radiation intensity during the day and higher elevations causing lower night time temperatures.

- 6) Using the General Climate Summary table, look under the column “Daily Extremes.” Here you can see the hottest and coldest temperatures that have occurred at the Haleakala Ranger Station over the last 50 years.

Now look at the graph “Daily Temperature Averages and Extremes” for a picture of how much the extreme temperatures differ from the averages. Explain how considering the extreme temperatures rather than simply average temperatures helps one understand the severe climate that the plants and animals of the alpine/aeolian region have to live in.

Answers should take into account the fact that temperatures generally vary much more than the averages suggest. The difference between the average minimum and maximum temperatures tends to be around 20° F. The difference between the extreme minimum and maximum temperatures tends to be around 35° F.

- 7) How do you think plants and animals are adapted to living in an environment marked by dramatic fluctuations between daytime and nighttime temperatures? Explain.

Well-reasoned answers are acceptable.





# Is It REALLY Summer Every Day and Winter Every Night?

The high mountains of Hawai‘i have what is called a “tropical alpine environment.” High mountains in other countries within the tropics, such as Peru, New Guinea, and Venezuela have some things in common with the Hawaiian Islands. One of the interesting similarities is there is a greater temperature change between day and night than there is between summer and winter. This means that the plants and animals living here are adapted to extreme daily fluctuations.

This feature led one scientist to say that in these environments, it is “summer every day and winter every night.” But you shouldn’t take his word for it. See for yourself!

## Instructions

Find out if day-night temperature differences really are greater than summer-winter temperature differences on the upper slopes of Haleakalā.

- 1) Download your data from the Western Regional Climate Center at <[www.wrcc.dri.edu/](http://www.wrcc.dri.edu/)>.
  - Select “Western U.S. Climate Historical Summaries.” Scroll down to the colored map and select Hawai‘i.
  - Select “Haleakalā Ranger Station.”
  - Click and print the table on the right side, “Period of Record Monthly Climate Summary.”
  - Scroll down the left side, find “Period of Record General Climate Summary Tables” and select “Temperature.” Click on the table and print it.
  - To see the extreme temperatures in chart form, select “Daily Extremes and Averages.” Click on the graph and print it.
- 2) Using the Monthly Climate Summary, find the annual average maximum and minimum temperatures on the far right side of the page. Circle those numbers on the table.

What is the difference between these temperatures? \_\_\_\_\_

*This gives you the difference between the average day and night temperatures.*

- 3) Using the same table, look at “Average Max. Temperature” and find the highest and lowest numbers. Circle those numbers on the table.

In which month is the highest average maximum temperature? \_\_\_\_\_

In which month is the lowest average maximum temperature? \_\_\_\_\_

What is the difference between these two numbers? \_\_\_\_\_

*This gives you the difference in the daytime temperatures between winter and summer.*



- 4) Do you think it is fair to say that, at the upper elevations of Haleakalā, it is “summer every day and winter every night”? Why or why not?
  
- 5) The climate summary information you are using from the Internet is based on readings from a station at approximately 2134 meters (7000 feet) at the lower edge of the alpine/aeolian zone. How would you expect day-night temperature differences in the summit area (the upper reaches of the alpine/aeolian zone) to compare to temperatures from the lower elevation? Explain your answer.
  
- 6) Using the General Climate Summary table look under the column “Daily Extremes.” Here you can see the hottest and coldest temperatures that have occurred at the Haleakala Ranger Station over the last 50 years.

Now look at the graph “Daily Temperature Averages and Extremes” for a picture of how much the extreme temperatures differ from the averages. Explain how considering the extreme temperatures rather than simply average temperatures helps one understand the severe climate that the plants and animals of the alpine/aeolian region have to live in.

- 7) How do you think plants and animals are adapted to living in an environment marked by dramatic fluctuations between daytime and nighttime temperatures? Explain.



Alpine/Aeolian Unit 3

# Life in the *Kuahiwi* and *Kuamauna* Zones

## Overview

Keen observers of the islands' natural communities, Hawaiians described twelve zones, or types of natural communities, that spanned the islands from the ocean to the tops of the mountains. The two uppermost of the zones, the *kuahiwi* (backbone) and the *kuamauna* (back mountain), are the equivalent of the alpine/aeolian zone on Haleakalā.

*Kuahiwi* is the alpine desert area, generally closest to the summit, where few plants other than lichens and some tufts of grass grow. Here, the predominant form of life is insects. The *kuamauna* zone begins below the summit and extends into the summit basin. This is the area associated with the *'āhinahina*, the Haleakalā silversword. The silversword was once used in lei-making, and so abundant that visitors described the hillsides as shimmering with the silver color that the Hawaiians named it for.

The native species that live in the alpine/aeolian zone of Haleakalā are adapted to its extreme environmental conditions. This unit helps students learn about the main species that live in this zone, how they are adapted to live in this environment, and how they interact with each other.

## Length of Entire Unit

Six 50-minute periods

## Unit Focus Questions

- 1) How are organisms adapted to live in the alpine/aeolian ecosystem?
- 2) What are the main species that live in the alpine/aeolian ecosystem?
- 3) In what ways do organisms that live in the alpine/aeolian ecosystem relate to each other?



## Unit at a Glance

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### Activity #1

#### **Alpine/Aeolian Challenges and Adaptations**

Students learn about plant and animal adaptations to the harsh alpine/aeolian environment through a slide show and a group activity.

#### **Length**

One and one-half class periods

#### **Prerequisite Activity**

None

#### **Objectives**

- Identify key species living in the alpine/aeolian ecosystem.
- Link adaptive responses to environmental conditions in the alpine/aeolian ecosystem.

#### **DOE Grades 6-8 Science Standards and Benchmarks**

**UNITY AND DIVERSITY:** Students examine the unity and diversity of organisms and how they can be compared scientifically.

- Compare and contrast the body structures of organisms that contribute to their ability to survive and reproduce.

### Activity #2

#### **Holding On To Water Lab**

Students perform an experiment in which they replicate alpine/aeolian environmental conditions and devise structural features that prevent desiccation.

#### **Length**

One and one-half class periods

#### **Prerequisite Activity**

Activity #1 “Alpine/Aeolian Challenges and Adaptations”

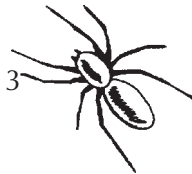
#### **Objectives**

- Create, observe, and analyze a model of how organisms adapt to dry environments.
- Make inferences based on the model about organisms that live in the alpine/aeolian ecosystem.
- Measure using a balance, and record data.
- Communicate observations related to organisms adapted to living in dry environments.

#### **DOE Grades 9-12 Science Standards and Benchmarks**

**DOING SCIENTIFIC INQUIRY:** Students demonstrate the skills necessary to engage in scientific inquiry.

- Develop and clarify questions and hypotheses that guide scientific investigations.
- Design and conduct scientific investigations to test hypotheses.
- Organize, analyze, validate, and display data/information in ways appropriate to scientific investigations.
- Formulate scientific explanations and conclusions and models using logic and evidence.
- Communicate and defend scientific explanations and conclusions.



### Activity #3

#### **Adaptations Game Show**

Students play a game to solidify and demonstrate their knowledge of environmental conditions in the alpine/aeolian ecosystem and how plant and animal life is adapted to these conditions.

#### **Length**

One class period

#### **Prerequisite Activity**

Activity #1 “Alpine/Aeolian Challenges and Adaptations”

#### **Objective**

- Link adaptive responses to environmental conditions in the alpine/aeolian ecosystem.

#### **DOE Grades 6-8 Science Standards and Benchmarks**

UNITY AND DIVERSITY: Students examine the unity and diversity of organisms and how they can be compared scientifically.

- Compare and contrast the body structures of organisms that contribute to their ability to survive and reproduce.

### Activity #4

#### **Web of Life Game**

Students play a game to explore the similarities and relationships among species in the alpine/aeolian ecosystem.

#### **Length**

Two class periods

#### **Prerequisite Activity**

Activity #1 “Alpine/Aeolian Challenges and Adaptations”

#### **Objectives**

- Identify key species represented in the alpine/aeolian zone.
- Identify similarities and differences among these organisms and how they are adapted to living in this ecosystem.
- Identify relationships among inhabitants of this ecosystem.

#### **DOE Grades 6-8 Science Standards and Benchmarks**

UNITY AND DIVERSITY: Students examine the unity and diversity of organisms and how they can be compared scientifically.

- Compare and contrast the body structures of organisms that contribute to their ability to survive and reproduce.

#### **DOE Grades 9-12 Science Standards and Benchmarks**

LIVING THE VALUES, ATTITUDES, AND COMMITMENTS OF THE INQUIRING MIND: Students apply the values, attitudes, and commitments characteristic of an inquiring mind.

- Ask questions to clarify or validate purpose, perspective, assumptions, interpretations, and implications of a problem, situation, or solution.



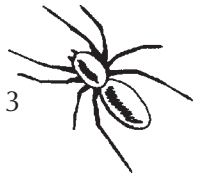
## Enrichment Ideas

- Build on Activity#2 “Holding On To Water Lab” by:
  - Running the lab a second time after students have read about how plants and animals are adapted to the alpine/aeolian conditions. Students can brainstorm other materials to use to protect their sponge insects based on the reading.
  - Simulating feeding and foraging behavior among insects. Have students leave their sponge insects exposed for one or two hours during the 24-hour period to “feed.”
  - Begin the lab with two or more sets of control and experimental sponges. Each set should have a different initial water weight, to simulate how quickly organisms in drought conditions lose water compared to normal moisture conditions.
- Have students do additional research on one of the main species in the alpine/aeolian zone. They may present their findings to the class, create a visual or multi-media presentation, or write a report.
- Play additional rounds of Activity #3 “Adaptations Game Show” using the species listed on the species cards, and the following categories:
  - Native plants
  - Native insects
  - Nonnative insects
- Encourage students to learn the scientific names of species by playing a round of Activity #3 “Adaptations Game Show” using the Latin genus and species names noted on the species cards. Use the same categories noted above.

## Resources for Further Reading and Research

Carlquist, Sherwin, *Hawai‘i: A Natural History*, 2nd ed., Pacific Tropical Botanical Garden, Lawai, Kaua‘i, Hawai‘i, 1980.

Medeiros, Arthur C. and Lloyd L. Loope, *Rare Animals and Plants of Haleakalā National Park*, Hawai‘i Natural History Association, Hawai‘i National Park, 1994, pp. 5-11.



Activity #1

# Alpine/Aeolian Challenges and Adaptations

## ● ● ● Class Period One *Slide Show and Challenges & Adaptations*

### Materials & Setup

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- Slide projector and screen
- “Living in the Extremes” slide show and script (pp. 7-9)

### *For each of four student groups*

- Student Page “Alpine/Aeolian Challenges and Adaptations” (p. 16)
- One set of Alpine/Aeolian Challenge and Adaptation Cards (master, pp. 12-15)
- Five paper clips
- Pencil with eraser

### Instructions

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- 1) Before presenting the slide show, divide the class into four teams. Encourage teams to listen carefully to the information presented for a later activity that focuses on how plants and animals are adapted to life in the alpine/aeolian ecosystem. Show the “Living in the Extremes” slide show, reading the script that accompanies it.
- 2) Hand out one copy of the Student Page “Alpine/Aeolian Challenges and Adaptations” and one set of Alpine/Aeolian Challenge and Adaptation Cards to each group.
- 3) Allow student groups the remainder of the class to complete the activity outlined on the student page by matching the adaptations cards to the challenges.

## ● ● ● Class Period Two *Challenges & Adaptations Discussion*

### Materials & Setup

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- “Alpine/Aeolian Challenges and Adaptations Answer Key” (teacher background, pp. 10-11)

### Instructions

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- 1) Take half a class period to discuss teams’ results from the previous day’s activity. Begin by asking one team to share the adaptations they matched to one of the challenges and explain their reasoning. Use the answer key to evaluate their responses, keeping in mind that logical reasoning may lead students to slightly different responses in some cases.
- 2) Continue the discussion by asking other teams to discuss their responses to each challenge until all have been covered.



## Journal Ideas

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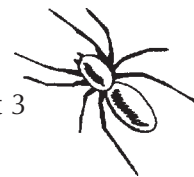
- How do you think ancient Hawaiians could have protected themselves from the environmental extremes of the alpine/aeolian ecosystem?
- If you were going to spend several days in the summit area of Haleakalā, how would you protect yourself from the environmental conditions?
- Compare the things that people can do to protect themselves with plant and animal adaptations that allow them to survive in the alpine/aeolian ecosystem.

## Assessment Tools

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- Participation in group activity and class discussions
- Student Page “Alpine/Aeolian Challenges and Adaptations” (teacher version, pp. 10-11)
- Journal entries





## Teacher Background

# “Living in the Extremes” Slide Show

*Photos courtesy of Haleakalā National Park, unless otherwise noted*

### Slide 1 – Scenery shot

Welcome to Haleakalā. What comes to mind for you when you think about the top of Haleakalā? (Have students call out answers.)

### Slide 2 – Archaeological sites near Pu‘u Naue

In Hawaiian tradition, this is the sacred House of the Sun. At the height of Hawaiian society, this place was revered as an especially sacred place and visited by few people. *Kāhuna*, Hawaiian spiritual leaders and elders, came here for meditation and to receive spiritual information. Important people were buried up here. There are places where people buried *nā piko* (umbilical cords) of their babies to make sure that they would grow well and that no one had the power to manipulate them.

### Slide 3 - Hawaiian adze quarry

Hawaiians constructed shelters in the summit area, but no one lived there. Among those who were given permission to enter this sacred place were men who quarried basalt rock for making adzes and other tools.

### Slide 4 – Sunrise shot (Photo: Jeff Bagshaw)

Before going to the summit of Haleakalā, early Hawaiians had to ask permission from human authorities and from the gods. Today, many Hawaiians still pray for permission from the land itself before they go to the summit. This area is no less a sacred place today than it was in times past.

The sun has always been an important part of traditional Hawaiian stories about Haleakalā. Have any of you heard the story of how Māui snared the sun? Here’s how it goes:

Early one day, long before sunrise, Māui, the mischievous demigod known throughout

the Pacific Islands, crept to the summit of Haleakalā, where he lay waiting for the sun’s first spidery legs to appear. As they came over the edge of the rim one by one, he lassoed each ray and secured it to a tree. The sun, now unable to move, begged for its freedom. Māui would not release the sun until it had promised to slow its daily rush across the sky—so that the people could do their work and his mother could finish the drying of the *kapa* (bark cloth) while there was yet daylight.

Māui left some of the ropes attached to the sun—to remind it of its promise to travel more slowly across the heavens. Every evening, just before the sun sets, the ropes can be seen trailing off into the night sky as daylight fades.

And to this day the sun is more careful to go slowly across the heavens, and the great mountain is known as Haleakalā—House of the Sun.

### Slide 5 – Summit basin above clouds

The top of this active—but not erupting—volcano rises high above the cloud layer that often covers its slopes. Up here, at the highest elevations on Maui, some people like to say that it’s summer every day and winter every night.

### Slide 6 - Sunrise with visitors

At night, temperatures can fall below freezing, especially if you factor in the windchill. You know this if you’ve ever gone up to the summit to watch the sun rise.

### Slide 7 – Ice crystals or “hoar frost” (Photo: Jeff Bagshaw)

Sometimes there are ice and frost. Most often, it’s just COLD.



**Slide 8** – Hikers on Sliding Sands Trail

During the day, however, temperatures can rise into the 80s, and solar radiation is intense. No matter what the temperature, you can easily get a sunburn up here! Human visitors can add or take off layers of clothing as the temperatures change, or put on a hat as the sun intensifies. But the plants and animals living near the top of Haleakalā, in the alpine/aeolian ecosystem, don't have that option.

**Slide 9** – *Na'ena'e* growing in a rocky spot  
(Photo: Jeff Bagshaw)

Up here, the plants and animals have to contend with challenges that go beyond these temperature extremes. In order to survive, they must also be adapted to exist in harsh winds, a dry atmosphere, infrequent and sporadic precipitation, the drying and heating effects of direct sunlight, and an environment with little food.

**Slide 10** – Scenic with *na'ena'e* in corner

Up here in the summit area, life isn't easy. The few species of plants and animals that do live here are special because they can survive in this harsh and most sacred of places. Let's take a look at what makes some of these plants and animals so well-adapted to life at the top, starting with *kūpaoa* or *na'ena'e*, the plant in the lower left corner of this picture. This plant has stiff, tough, concave leaves arranged close together to avoid drying by sun and wind.

Why would this leaf structure and arrangement be helpful to avoid drying by sun and wind? (Possible answers: The tough leaves have a hard shell that helps reduce water loss, leaves that are close together have less surface area exposed to direct sun and wind than leaves that are far apart.)

**Slide 11** - '*Āhinahina*

Does anyone know what this plant is? This is the '*āhinahina*, or Haleakalā silversword. It's found only here, near the top of Haleakalā. Silverswords have succulent leaves with gel-like substances and oils that store water and help prevent freezing. Tiny silver-colored leaf hairs that give the plant its name reflect bright sunlight.

**Slide 12** – Silversword closeup

What advantage would it be for a silversword to have leaves that reflect bright sunlight? (Answer: Help to keep the plant cool and retain water during the hot days and intense sunlight.)

**Slide 13** - Hawaiian long-horned beetle larva

This is the larva of a Hawaiian long-horned beetle. These beetles, like many other insects in the alpine/aeolian zone, directly depend on the silversword for their existence. The larva bores into the lower stems and roots of the plant where they feed on the woody tissue until they pupate and change into adults.

Carabid beetles are another type of insect that lives in the alpine/aeolian ecosystem. They are scavenger-predators that feed in part on insects that are blown in on upslope winds.

**Slide 14** - Wolf spider

This large spider constructs shallow burrows under the rocks and cinder. It cements leaves and other windblown debris together to form a circular refuge that protects it from the cold, dry climate.

**Slide 15** - '*Ua'u*, the Hawaiian dark-rumped petrel

These seabirds nest primarily in burrows dug in cinders along the upper slopes of the mountain. They use this habitat only for nesting and the parents fly out each day to forage for food at sea. '*Ua'u* nesting success depends on precise timing,



to avoid seasonal temperature extremes that could kill young nestlings. An 'ua'u pair raises just one chick per year. The strong pair bond of the 'ua'u male and female also helps these birds reproduce successfully. Parent birds share responsibility for incubating the egg and rearing the young bird.

**Slide 16** - Haleakalā flightless moth

This small moth has dagger-shaped wings and walks and hops rather than flying. Originally there were no natural predators in this habitat, so it didn't need wings to escape. Now it is preyed on by carnivorous nonnative yellowjackets and Argentine ants.

**Slide 17** – *Tetramolopium*

Many alpine plants are members of the sun-flower family and have disc or ray flowers that produce a large number of small seeds. These are accessible to moths, beetles, and other small insects and are easily spread by the wind.

**Slide 18** – Petrel habitat

The summit of the sacred house of the sun tests all that might enter or live there with high winds, scorching sun, freezing nights, sparse rainfall, and a substrate that doesn't hold water.

**Slide 19** – Lava bomb in shape of bird, Magnetic Peak

This bird is obviously well adapted and well camouflaged for living in the harsh extremes of the alpine/aeolian zone. (Note: This lava bomb, shaped like a bird, has broken due to the elements since the photo was taken.)



## Teacher Background

# Alpine/Aeolian Challenges and Adaptations

Use this answer key to evaluate student performance on the activity. Note that well-reasoned responses that do not match this key are acceptable. Key numbers match those on the adaptations cards and parenthetical notes following many of the adaptations provide you more information for discussion and explanation.

## Extreme Challenge #1:

### Dry Conditions

- Low rainfall levels and low humidity
- Winds that draw moisture out of plant tissues and out of the ground surface
- Sparse, periodic rains and a long dry season
- Quick water drainage through the lava and cinders
- No ponds or even puddles

### Adaptations

- 1 Some plants, like this *'āhinahina*, have succulent leaves that contain gel-like tissues and oils. (These tissues retain and store water.)
- 4 Insects like this Hawaiian ground beetle (*Barypristus rupicola*) have thick exoskeletons. (These help prevent water loss.)
- 7 Many insects become semi-dormant or go into deep burrows for extended times.
- 12 Many plants have large networks of spreading roots. (These networks allow plants to draw in large amounts of water quickly.)

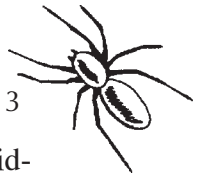
## Extreme Challenge #2:

### Winds

Dry air and winds draw moisture out of the soil and out of plant and animal tissues. Winds contribute to cold temperatures, especially at night. High winds cause damage to soft plant stems and leaves and make flight difficult for insects. On the other hand, the upslope winds blow insects and other organic matter (such as leaves) into the alpine/aeolian zone, providing nutrients and other resources.

### Adaptations

- 5 Some plants, like this *na'ena'e*, have waxy leaf surfaces, tough leaves, and strong woody stems. (These characteristics provide strength and durability against the wind.)
- 6 Tall flower stems or flowers on branch ends release small seeds (which may then be easily transported by winds).
- 8 Some insects are flightless. (This keeps them out of the wind. Biologists believe flightlessness evolved in response to the absence of mammalian predators. Flying drains energy and may have little adaptive value where there are no major predators to escape.)
- 9 Many alpine/aeolian insects are scavenger-predators that eat dead and stunned insects as well as plant matter. (These nutrient sources are blown in on the winds.)
- 11 On some plants, compact, dense foliage grows close to the ground (where it is out of the wind).
- 13 Many insects take shelter in crevices or under rocks.
- 14 Some insects use windblown leaves and other debris in constructing burrows or larval tubes.



### Extreme Challenge #3: Cold Nighttime and Seasonal Temperatures

Frost and ice often form on the ground and around plants. Occasionally it snows. Freezing can damage or destroy soft leaves and sensitive new growth and flowering parts.

#### Adaptations

- 1 Some plants, like this *'āhinahina*, have succulent leaves that contain gel-like tissues and oils. (These help prevent freezing and cell damage.)
- 2 Many larval forms, such as this Cerambycid moth larva, burrow into plant stems or roots (where they live, sheltered from the cold).
- 3 Some plants, like the *'āhinahina*, grow in a rosette form. (This growth form holds warmth in the center of the plant.)
- 10 A covering of small hairs grows on leaf surfaces (insulating them from cold).
- 16 Some insects and their larvae are covered with hairs (which may help to insulate them from the cold).
- 17 Many insects have seasonal life cycles. Moth larvae, for example, are sheltered in a chrysalis in winter, emerging in the spring as plants begin to flower.
- 21 Some adult insects build burrows.

### Extreme Challenge #4: Intense Solar Radiation

Intense sunlight can cause rapid expiration of water, overheating, and cellular damage in plants and animals alike. The heating effect of the sun is intensified by dark colored lava rocks and soils that become extremely warm over the course of a sunny day.

#### Adaptations

- 15 Leaf surfaces are covered by small, silvery hairs or waxy coatings. (These reflect the sun's rays, insulate leaf surfaces from extreme heat, and help hold in moisture.)

- 18 Many insects are active during the mid-morning hours and around dusk. During mid-day, they seek shelter in crevices, under rocks, or in burrows.
- 22 Light-colored leaves spread out from the plants. (These help shade the dark cinders and lava rock below the plant from the sun, protecting roots from overheating.)
- 23 Some insects burrow in cinders all day and feed at night.

### Extreme Challenge #5: Pollination and Seed Dispersal

Many insects are small and flightless—some are not particularly efficient pollinators. Moths and beetles are the most numerous types of insects in the alpine/aeolian ecosystem. They act as both pollinators and predators to plants. There are too few birds and no native rodents to help plants disperse seeds.

#### Adaptations

- 19 Many plants have disc or ray flowers that look like small sunflowers. (These open flower shapes are accessible to moths, beetles, and other small insects.)
- 20 Some plant seeds have hard coatings (which protect against predation).
- 24 Plants produce large numbers of seeds (which is an advantage when it is difficult to produce seeds at all).
- 25 Seeds are small (so they are easily dispersed by winds and rain).



## Alpine/Aeolian Challenge and Adaptation Cards

### Extreme Challenge #1: Dry Conditions

- Low rainfall levels and low humidity
- Winds that draw moisture out of plant tissues and out of the ground surface
- Sparse, periodic rains and a long dry season
- Quick water drainage through the lava and cinders
- No ponds or even puddles

### Extreme Challenge #2: Winds

Dry air and winds draw moisture out of the soil and out of plant and animal tissues. Winds contribute to cold temperatures, especially at night. High winds cause damage to soft plant stems and leaves and make flight difficult for insects. On the other hand, the upslope winds blow insects and other organic matter (such as leaves) into the alpine/aeolian zone, providing nutrients and other resources.

### Extreme Challenge #3: Cold Nighttime and Seasonal Temperatures

Frost and ice often form on the ground and around plants. Occasionally it snows. Freezing can damage or destroy soft leaves and sensitive new growth and flowering parts.

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### Adaptation #1

Some plants, like this 'āhinahina, have succulent leaves that contain gel-like tissues and oils.

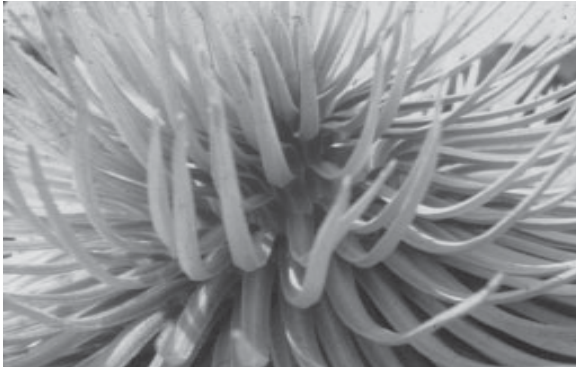


Photo: Haleakalā National Park

### Adaptation #3

Some plants, like this 'āhinahina (photographed from the top), grow in a rosette form.

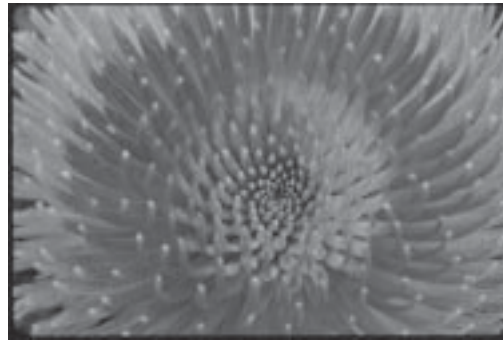


Photo: Haleakalā National Park

### Adaptation #1

Some plants, like this 'āhinahina, have succulent leaves that contain gel-like tissues and oils.

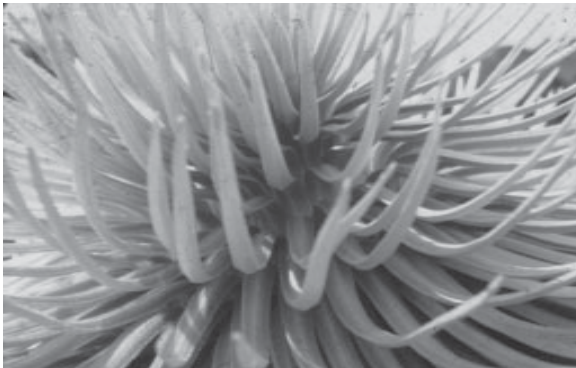


Photo: Haleakalā National Park

### Adaptation #4

Insects like this Hawaiian ground beetle (*Barypristus rupicola*) have thick outer or exoskeletons.

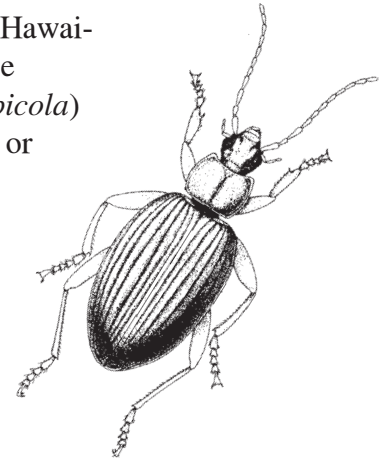


Image: Nancy Sidaras

### Adaptation #2

Many larval forms, such as this Cerambycid moth larva, burrow into plant stems or roots.



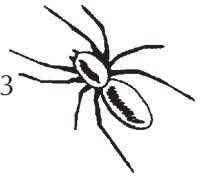
Photo: Haleakalā National Park

### Adaptation #5

Some plants, like this na'ena'e, have waxy leaf surfaces, tough leaves, and strong woody stems.



Photo: Haleakalā National Park



**Adaptation #6**

Tall flower stems or flowers on branch ends release small seeds.

**Adaptation #11**

On some plants, compact, dense foliage grows close to the ground.

**Adaptation #7**

Many insects become semi-dormant or go into deep burrows for extended times.

**Adaptation #12**

Many plants have a large network of spreading roots.

**Adaptation #8**

Some insects are flightless.

**Adaptation #13**

Many insects take shelter in crevices or under rocks.

**Adaptation #9**

Many alpine/aeolian insects are scavenger-predators that eat dead and stunned insects as well as plant matter.

**Adaptation #14**

Some insects use windblown leaves and other debris in constructing burrows or larval tubes.

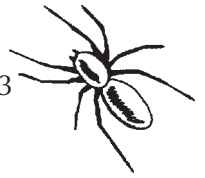
**Adaptation #10**

A covering of small hairs grows on leaf surfaces.

**Adaptation #15**

Leaf surfaces are covered by small, silvery hairs or waxy coatings.





**Adaptation #16**

Some insects and their larvae are covered with hairs.

**Adaptation #21**

Some adult insects build burrows.

**Adaptation #17**

Many insects have seasonal life cycles. Moth larvae, for example, are sheltered in a cocoon or chrysalis in winter, emerging in the spring as plants begin to flower.

**Adaptation #22**

Light-colored leaves spread out from the plants.

**Adaptation #18**

Many insects are active during the mid-morning hours and around dusk. During mid-day, they seek shelter in crevices, under rocks, or in burrows.

**Adaptation #23**

Some insects burrow in cinders all day and feed at night.

**Adaptation #19**

Many plants have disc or ray flowers that look like small sunflowers, with petals extending from a central, flat disc.

**Adaptation #24**

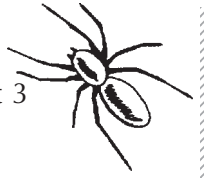
Plants produce large numbers of seeds.

**Adaptation #20**

Some plant seeds have hard coatings.

**Adaptation #25**

Seeds are small.



# Alpine/Aeolian Challenges and Adaptations

## Instructions

- 1) Have someone in your group read the following passage aloud to the rest of the group:

The small number of species that survive and thrive in the alpine/aeolian ecosystem are adapted to the conditions in this harsh environment. The plants and animals that live there may bear little resemblance to the ancestral species from which they descended.

Borne on the winds, transported by waves, powered by their own wings, or carried along by birds, most of the species that colonized the Hawaiian Islands came from Asia, North America, or Australia. Here they encountered conditions that might have been very different from their original habitats. Over millions of years, some of them have developed physical characteristics and behaviors that help them live in the extremes of the high elevations of Haleakalā.

In this activity, we will be given cards that describe some of the environmental challenges of the alpine/aeolian ecosystem. We will also have other cards which describe the physical and behavioral adaptations exhibited by native plants and animals. These adaptations may have developed in response to the environmental conditions in this zone; they may also have developed for other reasons. No matter what their cause, these characteristics allow plants and animals to survive and thrive in the harsh alpine/aeolian environment.

Our assignment is to match the adaptation cards to the environmental challenge they help organisms survive.

- 2) Read each of the five “Extreme Challenges” cards and place them on the table where the whole group can see them.
- 3) As a team, group the “Alpine/Aeolian Adaptations” cards with the challenge card they best fit.
  - Each challenge card will have several adaptations cards grouped with it.
  - There are multiple copies of the same adaptation card if it belongs with more than one challenge.
- 4) Keep track of your reasoning by writing down the reason each adaptation fits with the challenge on the adaptation card.
- 5) Once you have decided which adaptation cards match which challenge cards, paper clip the adaptation cards together with the matching challenge cards so that you are ready for the next class period, in which you will report on your results.



Activity #2

# Holding On To Water Lab

● ● ● **Class Period One** *Holding On To Water Lab (1/2 to 1 period)*

## Materials & Setup

---

- A sunny window sill or lamp
- Fan

*For each lab group of two to four students*

- Small sponges (four sponges of similar size and shape for each lab group)
- Water
- Natural materials such as leaves, sticks, rocks, nut shells, soil
- Small dishes or other impermeable surfaces
- Balance scale

*For each student*

- Student Page “Holding On To Water Lab” (pp. 19-20)

## Instructions

---

- 1) Divide the class into lab groups of two to four students.
- 2) Hand out the Student Page “Holding On To Water Lab Sheet” to each lab group.
- 3) Explain that the sponges in this activity represent insects that live in the alpine/aeolian environment near the summit of Haleakalā. In this environment—as in other dry environments—water is at a premium. The wind and intense sunlight have drying effects to which plants and insects in this environment have adapted.  
Each sponge-insect has a limited amount of water. The students’ job is to conserve that water over a 24-hour period. During that time, students are to protect their sponge-creatures in a manner that will best achieve this goal using only natural materials.

- 4) Have lab groups do steps one to three on the lab sheet.

● ● ● **Class Period Two** *Holding On To Water Lab, Continued*

## Materials & Setup

---

*For each lab group of two to four students*

- Balance scale

*For each student*

- Student Page “Learning From the Lab” (p. 21)



## Instructions

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- 1) Have individuals or groups share their experiments and results with the entire class. Afterward, conduct a class discussion reflecting on the activity.
  - a) Were there any patterns in lab results among groups? (For example, was the combination of sun and wind more drying than the sun alone?)
  - b) Which methods seemed to work better than others? Why? (Which lab groups had the smallest percent change in the weight of the protected sponges?)
  - c) Are the same methods effective for protection against the sun and wind? Why or why not?

Help students relate their strategies to insect adaptations (and those of other animal and plants) in the alpine/aeolian environment. (If you did Activity #1 in this unit, ask students to draw on what they learned for this discussion. If you did not do Activity #1, use the “Alpine/Aeolian Challenges and Adaptations Answer Key” on pages 10-11 as background to help you guide the discussion.)

- 2) Assign the Student Page “Learning From the Lab” as homework.

## Journal Ideas

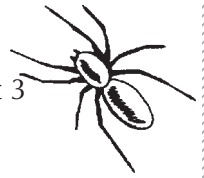
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- Relate how plants and animals have adapted to living in dry environments to things that humans do to protect themselves against dry, windy, sunny conditions.

## Assessment Tools

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- Student Page “Holding On To Water Lab Sheet”
- Lab conduct and methods
- Student Page “Learning From the Lab”



# Holding On To Water Lab

In this lab, you (or your lab group) will receive four small sponges. Each represents an insect that lives in the alpine/aeolian environment near the summit of Haleakalā. In this environment—as in other dry environments—water is at a premium. The wind and intense sunlight, in particular, have drying effects to which plants and insects in this environment have adapted.

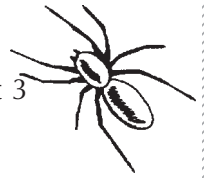
Each sponge-insect has a limited amount of water. Your job is to conserve that water over a 24-hour period. During that time, you are to protect your sponge-creatures in a manner that will best achieve this goal using only the natural materials your teacher provides.

## Divide the four sponges as follows

- Sponge #1 Protected from the sun according to your design and placed in a sunny window sill or under a lamp (that's turned off at night to simulate the sun).
- Sponge #2 Placed in the sunny window sill or under the lamp with no protection (a control sponge).
- Sponge #3 Protected from the sun and wind according to your design and placed under a fan AND in a sunny window sill or under a lamp (that's turned off at night to simulate the sun).
- Sponge #4 Placed under the fan AND in a sunny window sill or under a lamp with no protection (another control sponge).

## Instructions

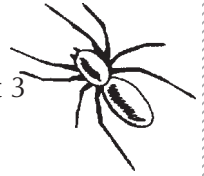
- 1) Soak each sponge with water. To measure the beginning moisture content, weigh your sponges and record the results on the next page.
- 2) Plan a strategy for using the materials provided to protect one of the sponges from the sun and one from sun and wind. Write down this strategy along with predictions of what will happen.
- 3) Protect your sponge-insects according to the strategies you devised and place them in small dishes or on other impermeable surfaces in the appropriate location. Use labels to distinguish each sponge from the others and your group's sponges from the rest of the class's.
- 4) At the end of the allotted time (roughly a 24-hour period), weigh sponges again, record weights, and make comparisons on the table on the next page.



# Holding On To Water Lab Sheet

- 1) On the following page write down the questions you are trying to answer through this lab.
- 2) After you've filled in the lab sheet, write your conclusions on the same piece of paper.

	Exposed to sun		Exposed to sun and wind	
	Protected	Unprotected (control)	Protected	Unprotected (control)
	Sponge #1	Sponge #2	Sponge #3	Sponge #4
Beginning weight (after being soaked with water)				
Describe your strategy for protecting the sponge-insect from drying and why you think it will work. (This is your hypothesis.)				
Prediction of the weight of the sponge after 24 hours				
Actual weight of the sponge after 24 hours				
Difference between the beginning and ending weights				
Percent change				



# Learning from the Lab

## Answer This Question as You Begin the Lab

- 1) What questions are you trying to answer through this lab?

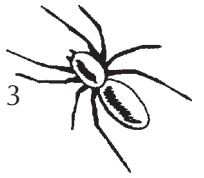
## Answer These Questions After You Have Completed the Lab

- 2) What are your conclusions from the lab? In other words, what answers did you receive to your questions?



- 3) Compare your strategies for protecting the sponges in the lab to the adaptations of animals and plants in the alpine/aeolian ecosystem.
- 4) If you were going to do the sponge lab again, what new ideas for protecting your sponge could you draw from the organisms that live in the alpine/aeolian ecosystem?





Activity #3

# Adaptations Game Show

## ● ● ● Class Period One *Adaptations Game Show*

### Materials & Setup

---

- Horn or obnoxious-sounding noisemaker
- Timer or watch with second hand
- Chalkboard or large dry-erase board

*For each team of two to four students*

- A bell, buzzer, or noisemaker.

### Instructions

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- 1) Conduct the “Adaptations Game Show” using the instructions detailed in the teacher background section (pp. 24-26).

### Journal Ideas

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- Imagine a plant or insect that is perfectly adapted for life in the alpine/aeolian ecosystem. Draw or describe that “perfect” organism.

### Assessment Tools

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- Participation and conduct during the game
- Demonstrated knowledge of content learned during the unit
- Journal entries



## Teacher Background

# Hosting the Adaptations Game Show

## Overview

This game helps students solidify and demonstrate their knowledge of environmental conditions in the alpine/aeolian ecosystem and how plant and animal life is adapted to these conditions.

The “Adaptations Game Show” is based on the T.V. game show, “Family Feud.” In “Family Feud,” teams compete with each other to provide the top eight or five (or another number) answers to a question that was posed to a group of survey participants. It is perhaps best known for the line, “Survey says...”

The basic idea behind the “Adaptations Game Show” is for teams of students to compete with each other to provide items on a list of adaptations that alpine/aeolian species exhibit to a particular environmental condition or challenge. The items on the list are based on readings and activities from the other activities in the unit.

## Instructions

- 1) Ask one student to volunteer to be the time-keeper. Give that student the stopwatch to use.
- 2) Divide the class into two to four teams. It is difficult to manage more than four teams in this game. Have students move around the classroom so that team members are sitting together.
- 3) Each team should pick one spokesperson. Give each spokesperson a bell or noisemaker. This will be used for signaling that the team wants to try to answer the question in front of the group.
- 4) Once the teams are settled in, go over the object and rules of the game, which are:

**Object:** To answer the questions quickly and correctly, identifying plant and animal adaptations that help them survive and thrive in the environmental conditions of the alpine/aeolian zone.

**Rules:** Each team has a bell or noisemaker to signal that it wants to try to answer a question. The spokesperson is the only team member who can use this noisemaker or bell. She or he is also the only team member who can give the answer to the game host (teacher). Other team members can give suggestions to the spokesperson during the time allowed.

Summarize the remaining rules and procedures based on the rest of the instructions given below.

- 5) Write an environmental challenge on the board. Leave several blank spaces under it. Each of these corresponds with a plant or animal adaptation to that challenge.

For example:

Challenge: It’s WINDY up here!

- 1.
  - 2.
  - 3.
  - 4.
  - 5.
  - 6.
- 6) Read the environmental challenge to the class and say, “Go.” The first team whose spokesperson rings the bell gets to try to name one adaptation that fits that challenge.



- 7) Once you recognize the team that will be playing, the spokesperson has **20 seconds** to give an answer. Have the timekeeper measure 20 seconds, give a warning when 15 seconds have passed, and call “Time” when 20 seconds are up.

During the allotted time, team members may call out ideas to the spokesperson. After considering the suggestions, the spokesperson will answer the challenge with one plant or animal adaptation.

If that adaptation IS on the game host’s list:

- **Write the answer** on the board in one of the blank spots.
- **Score a point** for that team.
- **Give that team another 20 seconds to come up with another adaptation.** Continue on until all adaptations have been listed OR until the team fails to give an answer that is on the game host’s list.

If the spokesperson does not give an answer within 20 seconds, OR if the answer given is not on the list:

- **Let the other teams have a chance** to add an adaptation. Read the challenge again, say “Go,” and allow the team that rings their bell first to play.

- 8) Continue this process until all adaptations for each challenge have been listed.

- Use an “applause meter.” If a team’s response is not on your list and they protest that it should be, let the spokesperson explain their reasoning. Then ask the rest of the class to applaud if they think the response is actually an adaptation to the environmental challenge. Use the level of applause and your own discretion about whether to score a point for the response.
- Make sure all teams have a chance to play, even if it means bending the rules a little. You’re the boss!
- Optional bonus round. At the end, let the team that has the fewest points play this bonus round, with the “prize” for getting both answers being the number of points needed to tie with the first place team.

Challenge: There’s nothing to eat up here!  
[You may explain this further by saying that the total amount of plant and animal life (or biomass) in the alpine/aeolian ecosystem is low compared to other ecosystems.]

- Eating insects blown in from below
- Going out to eat (petrels)

## Other Tips for Hosting the Alpine/Aeolian Adaptations Game

- Keep score on the board where everyone can see.
- Have fun and be dramatic! Use your own noisemaker to signal a team response that is not on your list of adaptations. Use a game show host voice or gimmicks.



## Game Host Challenge and Adaptations List

### Challenge: It's WINDY up here

- Tough leaves
- Strong, woody stems
- Tall flower stems with small seeds that can be easily carried by the wind
- Dense, compact foliage growing close to the ground
- Flightlessness
- Finding shelter in rock crevices or burrows
- Eating insects and plant materials blown in from elsewhere
- Using wind-blown debris in burrows or larval tubes

### Challenge: It's SUNNY and HOT during the day (and the ground is hot, too)

- Silver hairs (reflecting solar radiation)
- Light colored leaves
- Leaves that spread out (shading the ground under the plant)
- Activity at night, in the early mornings, or in the evenings (foraging, for example)
- Take shelter during the hot part of the day
- Shelter nests and young under rocks or in burrows (especially in plant roots or other parts where they'll have plenty to eat while they're growing up)
- Narrow and/or small leaves (minimize surface area exposed to the sun)

### Challenge: It's DRY up here!

- Succulent leaves (store water in their tissues)
- Waxy leaf surfaces
- Shallow, spreading roots that catch water as it filters through
- Insects take moisture from plant leaves and roots
- Thick exoskeletons
- Semi-dormancy or burrowing during long dry periods

### Challenge: It's COLD at night

- Leaves grow in a rosette form (protecting the center part of the plant)
- Hairy coverings (help insulate leaf tissues and insects)
- Succulent leaves containing a gel
- Small flowers that are encased in thick protective shell to protect sensitive flower parts
- Shelter nests and young in protective, insulating cases
- Take refuge in burrows or under rocks

### Challenge: It's RAINY and COLDER here during the winter

- Seasonal life cycles (moths, flowering plants)
- Leave during the winter (petrels)



Activity #4

# Web of Life Game

## ● ● ● Class Period One *Web of Life Game*

### Materials & Setup

---

- Alpine/Aeolian Connections Game Cards (master, pp. 30-45)  
(If there are not enough cards to go around, have students share a card.)
- A matching game card black and white photocopy for each student to take home

### For each student

- Student Page “Web of Life Game” (pp. 46-47)
- Student Page “How Does Your Species Fit?” (p. 48)

### Instructions

---

- 1) Begin the class by writing these words next to each other on the board or overhead: “similarities” and “relationships.” Ask students to think of some similarities among students in the class and write some examples in a column beneath the word, “similarities.” Next ask students to think of some relationships among students in the class and again write examples in a column below the word, “relationships.” Explain to students that they will be looking for both similarities and relationships among species in the alpine/aeolian ecosystem during the game they will be playing.
- 2) Hand out the Student Page “Web of Life Game.” Conduct Part One of the game using the game cards provided with the curriculum and following the game instructions (pp. 28-29).
- 3) Assign the Student Page “How Does Your Species Fit?” as homework.

## ● ● ● Class Period Two *Web of Life Game, Continued*

### Materials & Set Up

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- Large pieces of paper and colored pencils or marking pens

### Instructions

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- 1) Conclude the “Web of Life Game” by completing Part Two.

### Journal Ideas

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- Answer the “Think About It . . .” question on your species game card.
- What have you learned about this ecosystem by studying the relationships among species?

### Assessment Tools

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- Student Page “Web of Life Game”
- Student Page “How Does Your Species Fit?”
- Journal entries



*Teacher Background*

## Playing the Web of Life Game

### Part One

- 1) Pass out one game card and one copy of the Student Page “Web of Life Game” to each student. Take a few minutes for students to look at their cards.
- 2) Tell students the object of this game is to fill in their sheets with as many connections to other species in the alpine/aeolian zone as they can by talking with other classmates and comparing notes about their species.

Review the student activity sheet with students. It describes three kinds of links that students might be looking for:

- a) Characteristics that a species shares with another species,
- b) Similar kinds of adaptations to the alpine/aeolian environment, and
- c) Ways in which a species interacts with other species.

Students may find other kinds of links, too, which may include similar habitat or use of habitat (e.g. petrels and wolf spiders both dig protective burrows).

- 3) **BE PREPARED FOR A SOMEWHAT CHAOTIC SCENE AS STUDENTS SORT OUT THEIR STRATEGIES AND LOOK FOR LINKS!**
- 4) If things quiet down too much, encourage students to study their cards for details that they might have missed or to look around the classroom for someone they haven’t talked to yet.
- 5) When the end of class is near, have students return to their seats. Assign the Student Page “How Does Your Species Fit?” as homework.

Also hand out black and white photocopies of game cards for students to take home. Each student should have the photocopy that corresponds to the game card he or she used during class. Students need the information on the game card as well as the completed game activity sheet to do this assignment.

### Part Two

- 1) Spend a few minutes with students reviewing some of the basic links within natural communities. Ideas you may want to cover include:
  - Dependent relationships and independence,
  - Presence or absence of a central species in a natural community,
  - Predator/prey relationships,
  - Parasitism,
  - Mutualistic relationships in which both organisms benefit, and
  - Food webs.
  - Ask students to identify others.
- 2) Divide students into small groups of four or five students each, and give them about 20 minutes to draw a picture representing relationships of species to each other in the alpine/aeolian zone. They do not have to cover every species in this drawing, but they should study their lists of links from the previous class to include as many species as they can.
- 3) After about 20 minutes have passed, have students create one collaborative drawing, with you or one of the students acting as scribe. During this time, direct the action, asking questions that help students consider key relationships using the following discussion questions:



## Discussion Questions

- 1) What did students learn about their species and about the alpine/aeolian ecosystem?
- 2) What might happen to the whole community if different species were removed? (Pick a range of individual species to focus on one at a time.)
- 3) What kinds of things might cause some of the relationships to be cut off?
- 4) Ask students to discuss and/or illustrate the possible effects of the introduced species (Argentine ant and Western yellowjacket) on the native web of life.

## Activity Option

### Materials & Setup

- Lengths of string or yarn in several different colors
- Scotch tape

### Instructions

Instead of, or in addition to, having students make drawings that represent species relationships in the alpine/aeolian ecosystem, try this:

- 1) After you go through the review of basic links within natural communities (Part Two, #1), work with students to assign different colors of string to different kinds of relationships.

For example, colors may be assigned to represent:

- Predator/prey relationships,
  - Parasitism,
  - Mutualistic relationships in which both organisms benefit, and
  - Others that students identify.
- 2) Have students whose species are related in each of these ways tape either end of the appropriately colored string to their laminated species cards as a way of visually emphasizing the connections.
  - 3) Go through the types of relationships one at a time at first. Then create a “web of life” for the alpine/aeolian zone by adding all of the relationships/string colors together.
  - 4) Follow up with the discussion questions, showing effects of removing species or cutting off relationships by cutting or removing the strings held by the student representing different species.
  - 5) Illustrate the importance of the silversword in the ecosystem by cutting all of the strings that connect the silversword to anything else. Ask students to explain how each of the connected species would be affected if the silversword were removed from the web.



# Web of Life Game Cards

## 'Āhinahina, Haleakalā Silversword (*Argyroxiphium sandwicense* subsp. *macrocephalum*) Family Asteraceae

**Status** Endemic to Haleakalā. Threatened.

**Habitat** Found only on the upper slopes of Haleakalā.

### Characteristics

- Cannot produce fertile seeds without cross-pollination. Depends on insect pollinators for survival.
- About a dozen endemic species of moths, beetles, and other insects are found only with silverswords.
- Leaves are covered with silvery-colored hairs that reflect sunlight and help to hold in heat.
- "Monocarpic"—meaning it flowers only once and then dies.
- Stiff, succulent leaves in a rosette form shelter the interior of the plant from excessive heat or cold. The leaves of the often-spherically shaped plants may help shade the dark cinders below them, protecting shallow roots from too much heat.

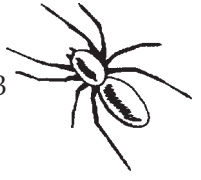
**Think about it:** How might invasions by non-native Argentine ants and Western yellowjackets threaten the 'āhinahina?

**Did you know?** The 'āhinahina is a part of a group of plants called the silversword alliance. These plants descended from a single ancestor species of tarweed that probably came originally from California. The 28 endemic Hawaiian species in the silversword alliance are in three genera: *Argyroxiphium*, *Dubautia*, and *Wilkesia*.



Photo: R.C. Zink, Haleakalā National Park





## Carabid Beetle (or Ground Beetle) (*Mauna frigida*)

Order Coleoptera, Family Carabidae

**Status** Endemic to Haleakalā. Of ten carabid beetle species recorded within the alpine/aeolian zone, nine are endemic to Haleakalā.

**Habitat** Five of the endemic carabid beetle species, including *Mauna frigida* have been found only on the upper 150 meters (492 feet) of the mountain's summit.

### Characteristics

- These five species are flightless scavenger-predators.
- Thick outer or exoskeletons protect them from water loss and extreme cold.

**Think about it:** These five species are extremely rare. Little is known about their current status or biology. Some of them may be extinct. How would you go about trying to find out?

**Did you know?** The 215 Hawaiian endemic carabid beetle species probably evolved from as few as six original immigrants.

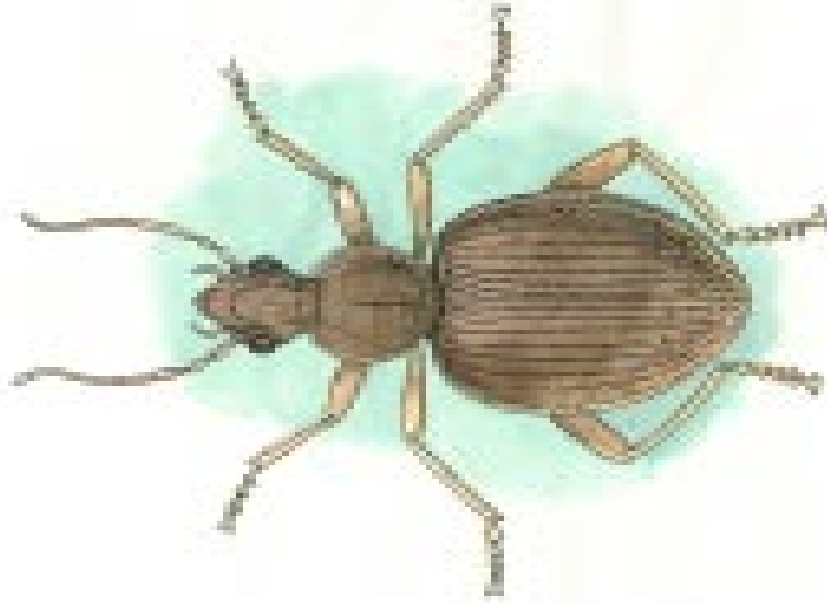
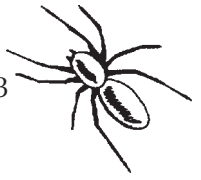


Image: Nancy Sidasaras



### Hawaiian Noctuid Moth (*Agrotis arenivolans*) Order Lepidoptera, Family Noctuidae

**Status** Endemic to Hawai'i.

**Habitat** • Larvae have been seen feeding on the leaves of the native shrubs *pūkiawe* and *na'ena'e*. They also feed on the seeds of the *āhinahina*.  
• Caterpillars burrow in cinders during the day and feed at night.

#### Characteristics

- Adults have a layer of long, thick hairs on their wings and bodies that help keep them warm, reflect sunlight, and prevent water loss.
- Adult noctuid moths visit flowers at night, probably acting as pollinators for native plants.

**Think about it:** Noctuid larvae are abundant in the alpine/aeolian zone. But wherever the Argentine ant is established, very few of these caterpillars can be found. What do you think is happening?

**Did you know?** The larvae (caterpillars) of most Lepidoptera species around the world feed on plants. But the larvae of at least one Hawaiian noctuid moth species in the alpine/aeolian zone feed on other insects as well as on the leaves of the few plants that occur in the area. Their arthropod prey is either dead or in a stupor from the cold night air.

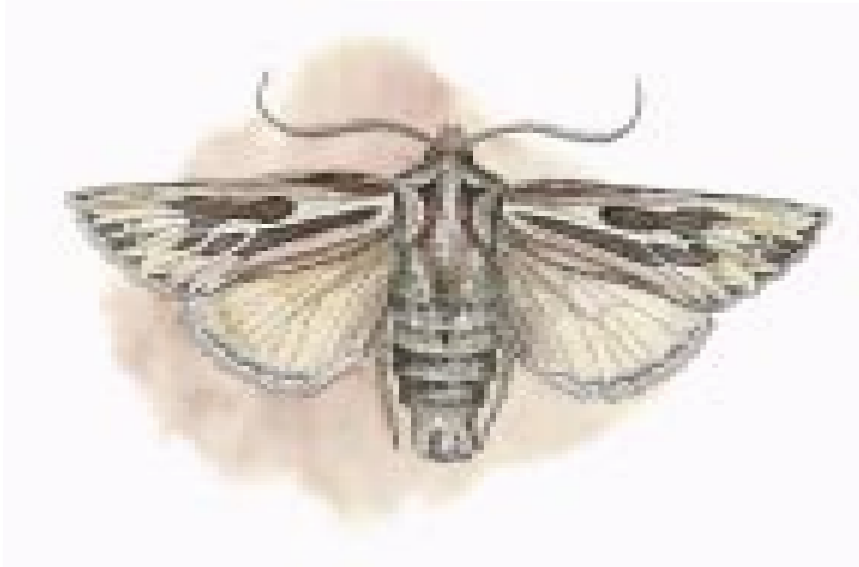


Image: Nancy Sidas



**Wolf Spider (*Lycosa hawaiiensis*)**  
Order Araneae, Family Lycosidae

**Status** Endemic to Haleakalā.

**Habitat** •Lives only at or near the mountain's summit.

- Makes shallow burrows under rocks by cementing windblown leaves and other detritus together with silk. The burrows protect them from the cold, dry climate.

**Characteristics**

- Normally dark in color, turns silver when hunting among the 'āhinahina rosettes.
- A predator-scavenger that hunts on the ground rather than building webs.
- A large spider, measuring between 3.5-5 cm (1.4-2 in) in length.

**Think about it:** How might a dark-colored body and long legs help a wolf spider survive in the cold temperatures of the alpine/aeolian zone?

**Did you know?** Mother wolf spiders carry silk egg sacs (larger than their own bodies) beneath them. As the young hatch, they ride on their mother's back while she hunts.



Photo: Haleakalā National Park



**Haleakalā Flightless Moth**  
**(*Hodegia [Thyrocopa] apatela*)**  
Order Lepidoptera, Family Gelechiidae

**Status** Endemic to Haleakalā.

**Habitat** • Found only on the upper slopes of Haleakalā.

• Seen most often on warm days in rocky areas but also attracted to lights at night.

**Characteristics**

- 1 1/4 cm (.5 in) long, silver-grey color.
- Has dagger-shaped wings but cannot fly. Instead, it walks and hops along the ground.
- Larvae live in silken tubes woven in with dried *na 'ena'e* leaves and bits of cinder.
- Larvae are covered with a thick layer of hair.

**Think about it:** What weather conditions in the alpine/aeolian zone might make it an advantage to walk instead of fly?

**Did you know?** Western yellowjackets prey on this moth. Researchers believe Argentine ants, too, would pose a threat if they became established in the moth's very small range.

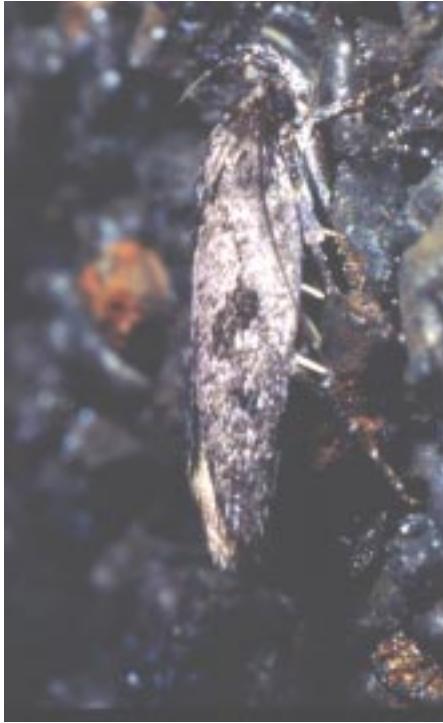


Photo: Eric Nishibayashi

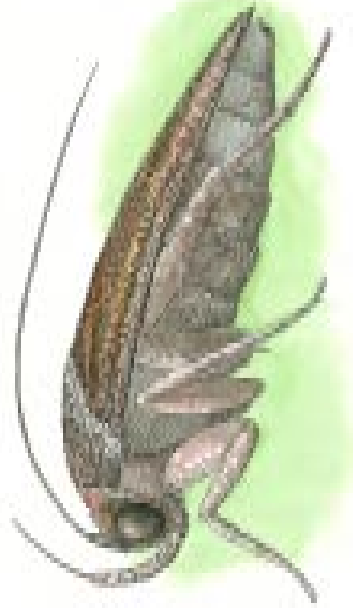
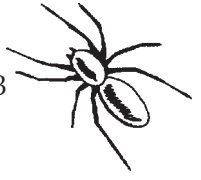


Image: Nancy Sitaras



**Argentine Ant (*Linepithema humile*)**  
(formerly *Iridomyrmex humilis*)  
Order Hymenoptera, Family Formicidae

**Status** Alien (probably native to Argentina and Brazil).

**Habitat** Have established a population near the edge of the alpine/aeolian zone.

**Characteristics**

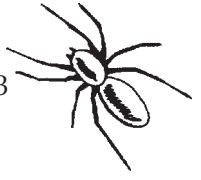
- On Haleakalā, areas occupied by Argentine ants show reduced numbers of many native insect species, including Lepidoptera larvae, carabid beetles, ground-nesting bees and wasps, and others.
- Noctuid moth caterpillars have been found among its prey.

**Think about it:** Researchers believe this species has the potential to eliminate most native arthropod species, including those that pollinate the *‘āhihihina* and other plants. How do you think this would change the ecology of the alpine/aeolian zone?

**Did you know?** Argentine ants are "eusocial" (truly social) insects. Biologists believe that social behavior gives insects a competitive edge over more solitary insects.



Image: Nancy Sidas



**Western Yellowjacket (*Vespula pensylvanica*)**  
Order Hymenoptera, Family Vespidae

**Status** Alien (native to western North America).

**Habitat** On warm summer days, very common on the mountain's summit, even where there is little plant cover.

**Characteristics**

- After dry winters, large numbers of worker wasps emerge in the late summer. They prey intensely on other arthropods.
- Haleakalā flightless moths have been found among their prey.

**Think about it:** Yellowjackets often prey on rare species with small ranges, native plant pollinators and flightless species. What effects do you think intense predation would have on the ecosystem?

**Did you know?** Western yellowjackets are "eusocial" (meaning truly social). Biologists believe that social behavior gives insects a competitive edge over more solitary insects.

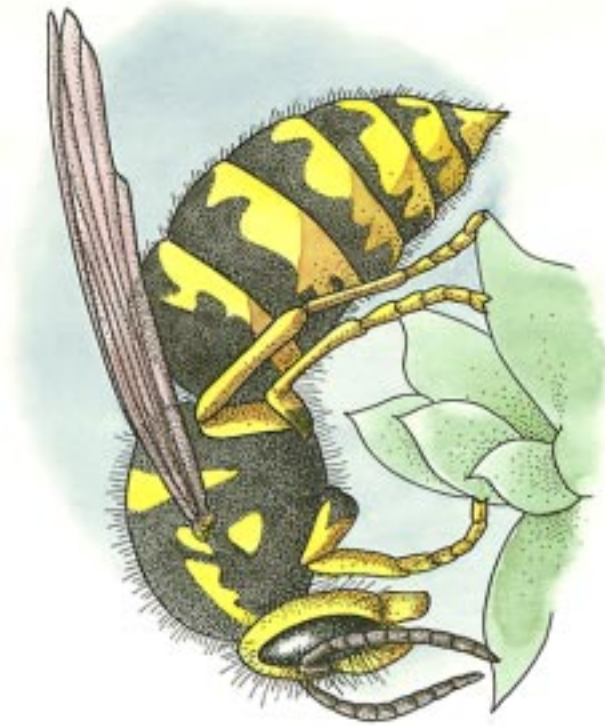


Image: Nancy Sidas



**Plant Hopper (*Nesosydne argroxiphii*)**  
Order Homoptera, Family Delphacidae

**Status** Endemic to Haleakalā.

**Habitat** Found only on *'āhinahina*.

**Characteristics**

- Silver colored, like the silversword.
- Sucks sap from the leaves of the silversword, but does no serious damage.
- Very tiny (1-2 mm or .04-.08 in).

**Think about it:** What advantage would a silver color be for an insect that lives exclusively on *'āhinahina* plants?

**Did you know?** Plant hoppers tap at different pitches to attract a mate. Each species has a different pattern of tapping.



Photo: Kim Martz and Forest Starr



## Hawaiian Long-Horned Beetle (*Plagithmysus terryi*)

Order Coleoptera, Family Cerambycidae

**Status** Endemic to Haleakalā.

**Habitat** Larvae bore into lower stems and roots of flowering ‘*āhinahina* plants.

### Characteristics

- Larvae feed on the woody tissue of the ‘*āhinahina* until they transform into adults.
- Mates and lays eggs in May and June when winter rains diminish, days are warm, and the silverswords begin to flower.

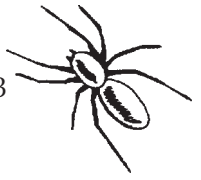
**Think about it:** The ‘*āhinahina* is the only known host plant for this beetle. How does this help explain the fact that, while an occasional plant will be so weakened that it topples over, most of the time the larvae cause no apparent damage?

**Did you know?** Over 136 species in the endemic genus *Plagithmysus* are believed to have evolved from a single ancestral species.



Image: Nancy Sidas





**Seed Bug (*Nysius communis*)**  
Order Heteroptera, Family Lygaeidae

**Status** Endemic to the Hawaiian Islands.

**Habitat** • Found in the summit area, as well as in other habitats on the mountain.

- Commonly seen on *‘āhinahina* and *na‘ena‘e* in the alpine/aeolian zone.
- In other ecosystems, found on other host plants such as *koa* and *‘ōhi‘a lehua*.

**Characteristics**

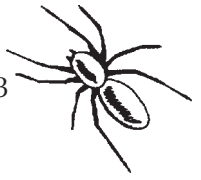
- Swarms are often seen in the summit area.
- Feeds on plant juices.

**Think about it:** How would piercing and sucking mouth parts help these insects obtain food?

**Did you know?** In the 1960s, swarms of various species of *Nysius* bugs sometimes interfered with visibility from the observatories on Haleakalā. Bushes surrounding the observatories were treated with the insecticide DDT to keep the insects out of the area.



Photo: Kim Martz  
and Forest Starr



**Tephritid Fly (*Trupanea cratericola*)**  
Order Diptera, Family Tephritidae

**Status** Endemic to Haleakalā.

**Habitat** Found only in association with ‘āhinahina (Haleakalā silversword).

**Characteristics**

- Females lay eggs in the buds of ‘āhinahina flowers. The eggs hatch as the flower develops.
- Larvae feed on seeds from ‘āhinahina.
- Wings are patterned.

**Think about it:** Females have a long ovipositor, the body part through which they lay eggs. Why would this characteristic be important for the survival of eggs and larvae?

**Did you know?** Nobody knows where these flies spend the winters.



Photo: Kim Martz and Forest Starr



**Hawaiian Yellow-Faced Bee**  
**(*Nesoprosopis [Hylaeus] volcanicus*)**  
Order Hymenoptera, Family Colletidae

**Status** Endemic to Haleakalā.

**Habitat** Lays eggs in a winding, silken tube nest, usually under a rock.

**Characteristics**

- Solitary, unlike the social honeybee that lives in cooperation with other bees.
- Visits flowers to gather pollen and nectar to feed its young.
- Small—only 6-12mm (.024-.048 in) long.

**Think about it:** Why would these small bees be so critical to the pollination of many native plants including *pūkiawe* and the *‘āhinahina*?

**Did you know?** Another species of Hawaiian yellow-faced bee (*N. volatilis*) found in the alpine/aeolian zone is a nest parasite. It lays its eggs in the nest of the bee species *N. volcanicus* or the related *N. nivalis*. It may visit flowers, as well, but only to gather nectar to feed itself.

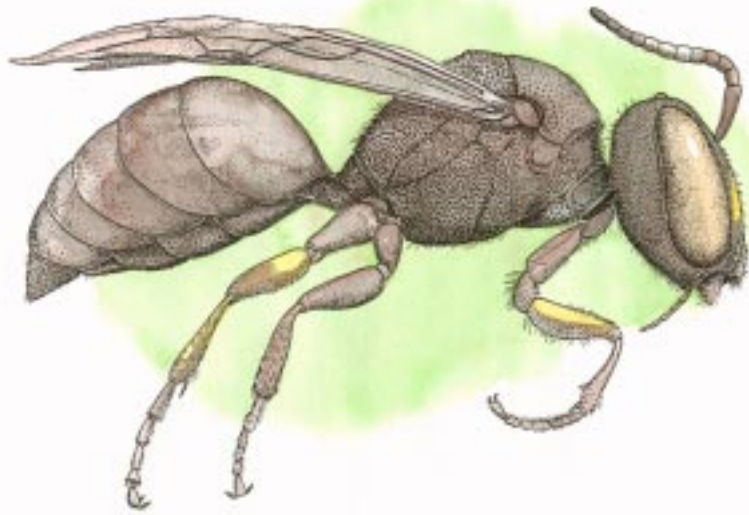


Image: Nancy Sitaras



**Na'ena'e or Kūpaoa (*Dubautia menziesii*)**  
Family Asteraceae

**Status** Endemic to Maui.

**Habitat** A common shrub in the alpine/aeolian zone.

**Characteristics**

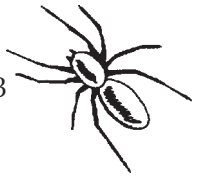
- Stiff, succulent, concave leaves similar to those on a silversword.
- Leaves grow along the stem in crowded ranks.
- From mid-June through November, yellow flowers are borne at the ends of branches.

**Think about it:** Why would bearing flowers at the ends of branches be an advantage for plants that rely on insects for pollination?

**Did you know?** Although it bears little resemblance to the 'āhinahina, the na'ena'e can hybridize with the 'āhinahina. Both belong to a group of plants called the silversword alliance. These plants descended from a single ancestor species of tarweed that probably came originally from California. The 28 endemic Hawaiian species in the silversword alliance are in three genera: *Argyroxiphium*, *Dubautia*, and *Wilkesia*.



Photo: Haleakalā National Park



***Pūkiawe (Styphelia tameiameia)***

Family Epacridaceae

**Status** Indigenous.

**Habitat** One of the most common shrubs in the alpine/aeolian ecosystem on Haleakalā.

**Characteristics**

- Tiny stiff, succulent leaves grow all around the stem. The leaves store water.
- Tiny white flowers and inedible, dry berries that may be red, pink, or white.

**Think about it...** *Pūkiawe* leaves are used in traditional Hawaiian medicine to treat colds and headaches. Lei-makers often use *pūkiawe* in elaborate *lei haku*. Should people be allowed to collect *pūkiawe* for these traditional uses within Haleakalā National Park, where plants and animals are protected from collection and hunting?

**Did you know?** The tiny Hawaiian yellow-faced bees are an important pollinator of this plant.



*Photo: Michele Archie*



**Tetramolopium**  
(*Tetramolopium humile* subsp. *haleakalae*)  
Family Asteraceae

**Status** Endemic to Haleakalā.

**Habitat** • Found only in the alpine/aeolian zone.

• Often grows sheltered by chunks of lava, large boulders, or crevices of lava flows.

**Characteristics**

• Small, narrow, hairy leaves.

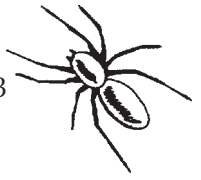
• Grows in a compact form low to the ground, like a dense cushion of leaves.

**Think about it:** How would small, hairy leaves and a cushion-like shape help this plant conserve water?

**Did you know?** Tetramolopium is a relative of the daisy and aster; two flowers that are common in home gardens and flower shops.



*Photo: Haleakalā National Park*



**'Ua'u, Hawaiian Dark-Rumped Petrel**  
**(*Pterodroma phaeopygia sandwichensis*)**  
Family Procellariidae

- Status**
- Endemic to the Hawaiian Islands.
  - Formerly known from all of the larger Hawaiian Islands.
  - Endangered.

- Habitat**
- Seabird that uses the alpine/aeolian zone only for nesting.
  - Most often nests in crevices or deep burrows dug in cinder along cliffs.

**Characteristics**

- Spends winters on the open ocean and return to nest on Haleakalā.
- Parent birds forage for squid and other food at sea, returning to tend and feed their young at night.

**Think about it:** How would introduced predators such as rats and mongoose pose a threat to the 'ua'u?

**Did you know?** Haleakalā is the only protected habitat for the 'ua'u. Ninety percent of the world's known population is found there.



Photo: Eric Nishibayashi



# Web of Life Game

## Instructions

This game has you looking for links between the species that is on your game card and other species in the alpine/aeolian zone. These links might be:

- Characteristics that your species shares with another species.
- Similar kinds of adaptations to the alpine/aeolian environment.
- Ways that your species interacts with other species.
- Other kinds of links. Be creative!

This is easy! Simply talk with your classmates who are holding cards for different species. Fill the name of the species in the table on the next page in the “Species” column. If you find a link, write that down in the other column. If you don’t find a link with that species, make a note about that, too.

## Strategy Hints

See how your species “fits” in the alpine/aeolian ecosystem. In order to do that, you’ll want to know about all the other species, being thorough in comparing notes with the holder of that species card.

Pay attention to the details on your card so you don’t miss any links. It’s not the number of “links” that counts—it’s that you learn how your species is related to other species in the alpine/aeolian zone.





Write the name of your species here:

Species	Links



# How Does Your Species Fit?

Using your game card and completed table of links with other species as background information, describe how your species relates to the other species in the alpine/aeolian ecosystem. Think about questions such as the following in writing your answer:

- What characteristics does your species share with other species (for example, food sources, coloration, shape, or behavior)?
- Do any of these characteristics seem to represent similar kinds of adaptations to the alpine/aeolian environment? Which environmental characteristics might they be adaptations to?
- How does your species interact with other species? Are there other species it depends upon?
- Are there any patterns that would help you describe how your species fits in the alpine/aeolian zone?

Write your answer in the space below, and use the other side of the sheet if you need more space:



Alpine/Aeolian Unit 4

# Good Critters, Bad Critters

## Overview

Native insects evolved along with the few plants that are able to survive in the alpine/aeolian ecosystem. Relationships among insects and plants in this ecosystem are only partially understood, but native insect pollinators are known to play a crucial role in plant reproduction. For example, insects are critical links in the reproduction of *‘āhinahina*, the Haleakalā silversword. This well-known endemic plant cannot self-pollinate.

Today, native insects in the alpine/aeolian zone are threatened by the invasion of non-native insects such as the Argentine ant. Native arthropod species (many of which are endemic to Haleakalā) evolved without ant predators because there are no ant species native to Hawai‘i.

To date, more than 40 species of ants have been collected in the Hawaiian Islands. Among these is *Linepithema humile*, the Argentine ant. This ant is of particular concern to resource managers and researchers at Haleakalā National Park. Unlike most other ant species that tend to be limited to sea level and lowland areas, the Argentine ant has become established at higher elevations. Researchers have identified two separate populations within park boundaries. These populations have been steadily expanding.

In this unit, students learn about the interdependence of native insects and plants in the alpine/aeolian ecosystem. They also learn about a threatening, invasive species of ant and what is being done to control the spread of these ants.

## Length of Entire Unit

Five or six 50-minute periods

## Unit Focus Questions

- 1) How do native plants and arthropods depend upon each other in the alpine/aeolian ecosystem?
- 2) What are the impacts of alien invaders such as the Argentine ant?
- 3) How do the role of native species and the biological and behavioral characteristics of alien species affect natural resource management decisions?



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**Unit at a Glance**

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**Activity #1****To Spray or Not to Spray**

Students propose a response to a management dilemma that arose in 1968, involving protecting ‘āhinahina, the Haleakalā silversword, from insect damage.

**Length**

One class period, followed by a homework assignment

**Prerequisite Activity**

None

**Objectives**

- Propose a course of action in response to a hypothetical conservation problem.
- Critique proposed measures based on new information.

**DOE Grades 9-12 Science Standards and Benchmarks**

**LIVING THE VALUES, ATTITUDES, AND COMMITMENTS OF THE INQUIRING MIND:** Students apply the values, attitudes, and commitments characteristic of an inquiring mind.

- Open-mindedness: When appropriate, modify ideas, explanations, and hypotheses based on empirical evidence or data.

**“MĀLAMA I KA ‘ĀINA”:** SUSTAINABILITY: Students make decisions needed to sustain life on Earth now and for future generations by considering the limited resources and fragile environmental conditions.

- Conservation of Resources: Analyze, evaluate, and propose possible solutions in sustaining life on Earth, considering the limited resources and fragile environmental conditions.

**Activity #2****Ant Alert: How Does Invasion Threaten Natives?**

Students compare the invasive Argentine ant to other ant species to understand why the Argentine ant is such a potential threat to the alpine/aeolian ecosystem on Haleakalā. In teams, they teach each other about the threat Argentine ants pose.

**Length**

Two or three class periods, preceded by homework reading

**Prerequisite Activity**

None

**Objectives**

- Identify and describe similarities and differences between Argentine ants and other ant species.
- Illustrate traditional Hawaiian social values and concepts using ant behavior as examples.
- Explain how Argentine ant biological and behavioral characteristics enable them to pose a threat to native Hawaiian insects and plants.

**DOE Grades 9-12 Science Standards and Benchmarks**

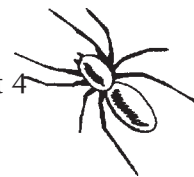
**DOING SCIENTIFIC INQUIRY:** Students demonstrate the skills necessary to engage in scientific inquiry.

- Formulate scientific explanations and conclusions and models using logic and evidence.

**USING UNIFYING CONCEPTS AND**

**THEMES:** Students use concepts and themes such as system, change, scale, and model to help them understand and explain the natural world.

- Change: Explain the effect of large and small disturbances on systems in the natural world.



## Activity #3

### Controlling the Argentine Ant

Students propose ideas for controlling the spread of Argentine ants in Haleakalā National Park, compare their ideas to what's already being done, and evaluate the efficacy of current control efforts.

#### Length

Two class periods, followed by a homework assignment

#### Prerequisite Activity

Activity #2 “Ant Alert: How Does Invasion Threaten Natives?”

#### Objectives

- Propose ideas for controlling the spread of Argentine ants in Haleakalā National Park.
- Perform calculations to assess the effectiveness of an experimental effort to control the spread of Argentine ant populations.

#### DOE Grades 9-12 Science Standards and Benchmarks

RELATING THE NATURE OF TECHNOLOGY TO SCIENCE: Students use the problem-solving process to address current issues involving human adaptation in the environment

- Collect, organize, and analyze information from reliable sources to identify alternative solutions.
- Evaluate the effectiveness of the actions taken to resolve the problem or issue and its overall effect on self, others, and the environment.

### Enrichment Ideas

- Do Internet research to find out more about the current status of silverswords on Maui and recent research on silversword ecology.
- Have an ant-baiting competition. Divide the class into groups and give each group an index card and small amounts of three types of bait (such as tuna fish or canned cat food, peanut butter, and honey). Students should smear a small amount of each kind of bait on a separate spot on the card, label the bait types, and then place their cards somewhere in or outside the classroom where they think the card is most likely to attract ants.
 

Let the cards sit undisturbed for 20-25 minutes while students write answers to these questions:

  - 1) Where did your group choose to place its bait card? Why do you think this is a likely place to attract ants?
  - 2) Which bait do you think ants will be most attracted to? Why?
  - 3) What other insects or animals do you think will be attracted to the bait card? Why?

Send student groups or representatives out to collect the bait cards and observe the presence of ants, the baits they are feeding on, whether there seem to be different kinds of ants present, and what other insects or animals are present.

Have students check their hypotheses against their observations, and discuss differences. You may want to announce the “gold, silver, and bronze medal winners” in the ant-baiting competition.
- Print the HINS report on the Argentine ant (see reference below). On pages 2-3, this report outlines methods used to control (or attempt control of) Argentine ants, including several chemical agents that have since been



outlawed. Have students research one or more of these outlawed chemicals focusing on its environmental and health effects. In reporting their findings, ask students to write or talk about factors that should be considered in selecting chemical pesticides for use at home, on farms or gardens, or in agricultural areas.

- Design an educational program or materials to help stop the spread of Argentine ants to other parts of Haleakalā National Park.

## Resources for Further Reading and Research

Carr, Gerald, Elizabeth Powell, and Donald Kyhos, “Self Incompatibility in the Hawaiian Madiinae (Compositae): An Exception to Baker’s Rule,” *Evolution*, Vol. 40, No. 2, 1986, pp. 430-434.

Kobayashi, Herbert K., *Ecology of the Silversword: Haleakala Crater, Hawaii. Final Report Hale N-3*, Hawai‘i Natural History Association, 1973.

Loope, Lloyd L., Arthur C. Medeiros, and F. R. Cole, *Proceedings of the Conference on Science in the National Parks, 1986, Volume 5: Management of Exotic Species in Natural Communities*, L. K. Thomas, Jr. (ed.), The U.S. National Park Service and The George Wright Society, 1988, pp. 52-62.

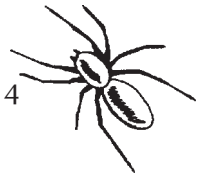
Loope, Lloyd L. and C. F. Crivellone, *Status of the Silverswords in Haleakalā National Park: Past and Present. Technical Report 58*, Cooperative National Park Resources Studies Unit, University of Hawai‘i at Manoa, 1986.

Medeiros, Arthur C. and Lloyd L. Loope, *Rare Animals and Plants of Haleakalā National Park*, Hawai‘i Natural History Association, 1994.

HNIS (Harmful Non-Indigenous Species) report for the Argentine ant (*Linepithema humile*) can be downloaded from <[www.hear.org/hnis/index.html#invertebrates](http://www.hear.org/hnis/index.html#invertebrates)>.

Hawai‘i Ecosystems at Risk, “Pest Ants in Hawai‘i” at <[www.hear.org/AlienSpeciesInHawaii/ants/index.html](http://www.hear.org/AlienSpeciesInHawaii/ants/index.html)>.

Myrmecology at <[www.myrmecology.org](http://www.myrmecology.org)>. This site includes general background on ants and the study of ants as well as a variety of links to other ant-related sites.



Activity #1

# To Spray or Not to Spray

## ● ● ● Class Period One *To Spray or Not to Spray?*

### Materials & Setup

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- Silversword image acetate (master, p. 7)
- Silversword species card from Alpine/Aeolian Unit 3, Activity #4 “Web of Life Game,” p. 30
- Overhead projector and screen

### For each student

- Student Page “What Would You Decide?” (pp. 8-9)
- Student Page “Now You Know . . .” (pp. 10-11)

### Instructions

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- 1) Show the acetate of the silversword. Ask students if they know what it is. Once you have identified this plant as the *‘āhinahina*, or Haleakalā silversword, ask students if they have ever seen this plant or know anything about it. Use the notes on the species cards to raise interesting points about the *‘āhinahina* as the discussion progresses.
- 2) Divide the class into groups of three or four students.
- 3) Hand out the Student Page “What Would You Decide?”
- 4) Give groups about 20 minutes to read the scenario, discuss alternative courses of action, and agree on one.
- 5) Bring the class back together and discuss the scenario and group decisions for the remainder of the class period. Have student groups present their courses of action and explain their reasoning. Then draw out common themes by asking questions such as these:
  - a) How easy was it to come to an agreement about what to do?
  - b) What were some of the disagreements or different points of view that came up?
  - c) Do you have any doubts or uncertainties about the course of action you chose? If so, what are they? Why did you decide to take this course of action despite those doubts?
- 6) Assign the Student Page “Now You Know . . .” as homework. Note that students will need to take home their copies of the “What Would You Decide?” student page as well to complete this assignment.

### Journal Ideas

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- Do you think it is important to protect native plants such as the *‘āhinahina* from possible extinction? Why or why not?
- Describe a decision you wish you could have changed later. What can you do to help make good decisions even if you don’t know what will happen in the future? How can resource managers use the same approaches to make good decisions about protecting native plants and animals?



## Assessment Tools

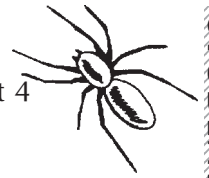
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- Participation and conduct in small groups
- Participation in class discussion
- Student Page “Now You Know . . .”
- Journal entries





‘Āhinahina (*Haleakalā silversword*) in bloom  
(Photo: R. C. Zink, Haleakalā National Park)



# What Would You Decide?

Take a trip more than thirty years back in time. The year is 1968. The superintendent of Haleakalā National Park has a tough decision to make.

Park staff members have become concerned about the damage that insects appear to be doing to ‘āhinahina, the Haleakalā silversword (*Argyroxiphium sandwicense* subsp. *macrocephalum*), one of the best-known plants in the park. Recent reports from an entomologist (a person who studies insects) and a park naturalist suggest that insects may be damaging the plants so that almost no seeds are produced.

‘Āhinahina was once so common in the summit area that many hillsides shimmered with the silvery plants, reminding visitors of winter or moonlit landscapes. In the late 1800s and early 1900s, visitors to the summit of Haleakalā would often collect the silverswords as souvenirs, uproot them for the fun of seeing the round plants bounce and roll down the cinder slopes, or dig them up for sale as garden plants.

Over the years, human vandalism along with browsing by domestic cattle and feral goats (free-roaming animals descended from domesticated goats that escaped or were turned loose) had reduced silversword numbers to a fraction of their former abundance. By the 1940s these problems were brought under control by the national park, but populations of this unique plant were not rebuilding as quickly as expected. Some populations even continued to decline.

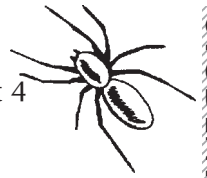
Now, with the news that insects appeared to be damaging the silverswords by eating the flowers and seeds, the superintendent is in a dilemma. Part of his job is to protect the native plants and animals found in the park. The silversword has become an important symbol of the park, recognized around the world. He wants to do everything in his power to make sure the ‘āhinahina survive.

There is a “pesticide” (substance toxic to pest insects or plants used to control their populations) that seems as though it could be effective on a range of insect species. This pesticide was used in the early 1960s on bushes around the observatories near the summit to control large concentrations of insects that sometimes interfered with the operation of the observatories. The insecticide appeared to be effective at killing insects on the vegetation and keeping them away for three to four months after each application.

Some people on the park staff say the superintendent should start a program for spraying the silverswords with this pesticide. They say this pesticide has a good chance of taking the pressure of insect predation off the silverswords and increasing their chances of reproducing.



Danny and a silversword  
(Photo: Haleakalā National Park)



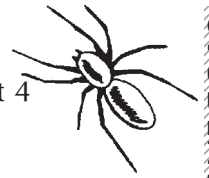
Other people on the park staff think the silverswords should not be sprayed. The silversword ecosystem includes several endemic insects (found only in Hawai‘i or only on Haleakalā) including flies, bees, moths, planthoppers, and beetles. These staff members believe there is too much risk of harming the native insect species that evolved along with the silversword.

Still other park staff members believe there needs to be more research before any decision is made. They point out that little is known about which insects are doing the most damage to ‘āhinahina, what effect the pesticide would have on different insect species, and whether spraying would be effective at all. Furthermore, they say, there’s not enough evidence to prove that insect predation is actually decreasing the silverswords’ ability to reproduce.

## Your Group’s Assignment

What do YOU think the superintendent should do?

- 1) Discuss with your group what you think the right decision would be and why.
- 2) Come to agreement on a course of action.
- 3) Be prepared to explain your reasoning when your group presents its decision to the rest of the class.



## Now You Know . . .

Beginning in the 1970s, there was more attention given to research about *‘āhinahina* and their habitat. Researchers, mostly based at the University of Hawai‘i and at the park, have added greatly to our knowledge about these magnificent plants. Here is some of what’s been learned about silverswords and insects since 1968.

- In 1973, botanist Herbert K. Kobayashi completed an extensive study of silversword ecology in the Haleakalā summit basin. Part of his research focused on the relationship between *‘āhinahina* and insects that have been observed causing damage to the plants. In his report, he points out three considerations that counter the commonly held view that insects are a main cause of declining silversword populations:

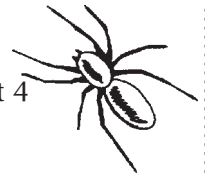
- 1) The insects that have been observed to do the most damage are larvae of insects specifically associated with the Haleakalā silversword. In other words, like several other insect species, they depend on *‘āhinahina* for their survival. These insects evolved over a long period of time together with the silversword, and would run out of food if their larvae damaged the silverswords so badly that they could not reproduce.
- 2) In 1969 and 1971, Kobayashi examined hundreds of *‘āhinahina* flowers and found none with seeds completely destroyed by insects. Even the most heavily damaged populations had some viable (capable of germination) seeds available for dispersal. Viable seeds survive because the insects do not eat the entire flower.
- 3) Large, dense populations suffer the most insect damage, while smaller isolated populations are the least damaged. Despite appar-

ently heavy insect infestations, large populations of *‘āhinahina* have remained on the cinder cones and lava flows for at least 100 years, so high infestation does not necessarily lead to a drop in number. Even if a larger population were to be drastically reduced, the smaller, more isolated populations may then serve to re-establish larger populations.

- In the mid-1980s, University of Hawai‘i botanists Gerald Carr and Elizabeth Powell teamed up with Donald Kyhos from the University of California to learn that silverswords cannot produce fertile seeds without cross-pollinating with other plants. *‘Āhinahina*, which flower only once after many years of growth, depend on insect pollinators in order to reproduce.

- According to Lloyd Loope and Art Medeiros, both researchers at Haleakalā National Park, the greatest threat to *‘āhinahina* now appears to be the potential loss of its insect pollinators. These endemic insects may be threatened by the non-native Argentine ant, which has established itself in small and growing areas of silversword habitat. Park researchers and resource managers are working to control the spread of this invader.

- In his 1973 report on silversword ecology, Herbert Kobayashi expressed concern about trampling as a source of damage to young silversword plants. The *keiki* *‘āhinahina* are small and not always easily seen by hikers. And the cinders the plants grow in are easily displaced by trampling feet. As more people visit Haleakalā, Kobayashi warned that trampling would probably become a more important source of damage to silverswords. Researchers also need to be careful about damaging young *‘āhinahina*, especially when they are walking off-trail.



• The insecticide proposed for use on silversword insects in the 1960s was DDT (1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane). DDT was also used around the observatories in 1964. DDT grew to be a popular insecticide largely because it was so effective against the mosquito that spreads malaria and the louse that carries typhus. It seemed to be an ideal pesticide because it was cheap and because laboratory tests showed that it was relatively nontoxic to mammals.



Today, visitors are encouraged to stay away from the silverswords to avoid trampling keiki plants and damaging shallow roots. (Photo: Haleakalā National Park)

In 1962, Rachel Carson’s book, *Silent Spring*, was published. In it, Carson looked at modern agriculture and its dependence on chemical insecticides. DDT was one of those insecticides. At the time, DDT was routinely sprayed on beans, peanuts, tomatoes, and other crops. Carson laid out a compelling collection of evidence about the environmental and human health problems associated with DDT. She pointed to studies that correlated fish and bird mortality with DDT. Where it was used against Dutch elm disease, for example, DDT killed earthworms that fed on fallen leaves, as well as robins that fed on the earthworms. Falcons and other birds of prey contaminated with DDT produced thin-shelled eggs that hatched before fully maturing.

*Silent Spring* helped spark an uproar among U.S. citizens concerned about health and the environment. It is often identified as the beginning of the modern environmental movement. In 1972, the federal government bowed to public pressure and ordered a ban on DDT in the United States.

### ‘Āhinahina on the Rebound

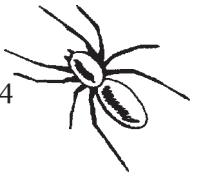
(Census of silverswords from Ka Moa o Pele cinder cone)

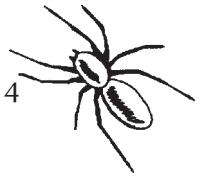
Year	Number of Plants
1935	1470
1962	1248
1971	3990
1981	6405
1991	6019

### Your Assignment

Based on everything you’ve learned during this activity, write a one-to-two-page paper in which you:

- 1) Briefly describe your group’s response to the “What Would You Decide?” scenario; and
- 2) Explain whether and how the information in this student page changes your thinking about what the superintendent in that scenario should do.





Activity #2

# Ant Alert: How Does Invasion Threaten Natives?

## ● ● ● In Advance *Student Reading*

- Assign the Student Page “That Ant is a Tramp” as homework reading (pp. 20-23).

## ● ● ● Class Period One *Ants Video*

### Materials & Setup \_\_\_\_\_

- *Nova* video, “Ants! Little Creatures Who Run the World” (included with this curriculum)
- VCR

#### *For each student*

- Student Page “Ant Video Note Sheet” (pp. 24-25)

### Instructions \_\_\_\_\_

- 1) Watch the *Nova* video entitled, “Ants! Little Creatures that Run the World.” The entire video lasts approximately 1 hour, so if you have a shorter period than that, play video from beginning through the leafcutter ant segment. This is 47 minutes of run time. Or play as much of the video as you can during the class.
- 2) During the video, ask students to fill in the Student Page “Ant Video Note Sheet.” Let students know they do not necessarily need to remember the species names of different kinds of ants on this note sheet. However, they should be able to describe the ant species well enough that someone who’s watched the video would know which ant they are describing.
- 3) As homework, have students review their class notes and the “Argentine Ants” student page from the previous homework assignment to prepare for a brief in-class quiz the following class period.

## ● ● ● Class Period Two *Argentine Ants Teaching Teams Preparation*

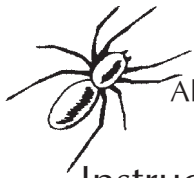
### Materials & Setup \_\_\_\_\_

#### *For each student*

- Student Page “Argentine Ants Quiz” (pp. 37-38)

#### *For each student teaching team*

- One copy of the appropriate topic set (see class period two instructions) from the Student Page “Argentine Ants Teaching Teams Background” for each team member (pp. 26-36)



## Instructions

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- 1) Have students complete the Student Page “Argentine Ants Quiz.”
- 2) Divide the class into four or more teams. Each team should consist of at least three students. Assign each team a topic from the list below, making sure that each topic is covered by at least one team. Explain to students that they will be working in teams to teach the rest of the class about a specific topic related to Argentine ants and the threat they pose to native ecosystems on Maui.  
Topic #1: The location and spread of Argentine ants in Haleakalā National Park  
Topic #2: The threat Argentine ants pose to native arthropods in the alpine/aeolian ecosystem  
Topic #3: Biological and behavioral characteristics that make Argentine ants a strong invader  
Topic #4: Characteristics of Argentine ants that affect how they spread and can be controlled
- 3) Hand out the appropriate section of the Student Page “Argentine Ants Teaching Teams Background” to the teams, making sure each team member receives a copy of the information on the group’s topic.
- 4) Have team members use the information from the initial homework reading and the student page you just handed out to develop a creative presentation that will teach other students about the team’s topic. Ideas include writing and performing a song or chant, making a visual representation, developing a multi-media presentation, or performing a skit or comedy routine.
- 5) Each team must also come up with two questions they want other students to be able to answer after their team presentation and have these questions written on a piece of paper that can be handed in.

## Teaching Option

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- If you want to pare down this activity from three class periods to two, or prefer to present the information yourself, substitute a lecture and discussion format. Use the Student Page “Argentine Ants Teaching Teams Background” for your background notes.

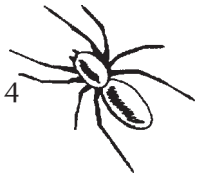
### ● ● ● Class Period Three *Team Presentations*

## Instructions

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- 1) Invite members of each team to stand up in front of the class and make their presentation. Go in the order in which the topics are listed above. Complete all the team presentations on a given topic before moving on to the next one. Prior to each presentation, have the team hand in its list of two questions that other students should learn to answer based on the presentation.
- 2) If there is time at the end of the class, have a class discussion focusing on the implications of what students have learned about Argentine ants for resource management in the park.
- 3) Select one or more questions from presentations on each topic, and either orally assign them as homework, or use them to prepare a quiz for the following class period or a later homework assignment.





## Journal Ideas

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- Do you think resource managers in Halekalā National Park should make eradicating or controlling nonnative species such as Argentine ants a top priority? Why or why not?
- Think about the social structure and operation of ant colonies. Identify one aspect of ant behavior from which humans could learn valuable lessons and explain how that would benefit people. Then identify one aspect of ant behavior that would be destructive if people adopted it, and explain your thinking.

## Assessment Tools

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- Student Page “Ant Video Note Sheet” (teacher version, pp. 16-17)
- Student Page “Argentine Ants Quiz” (teacher version, pp. 18-19)
- Participation in preparing and delivering team presentation
- Team presentations: Assess on the basis of creativity, conformance with information provided, and thoroughness in answering the questions the team identified for other students.
- Journal entries



# Ants Video Note Sheet

This list of possible responses is not complete, but provides guidelines for assessment and discussion.

Write something you learned from the video about ants, termites, or other social insects that illustrates each of these traditional Hawaiian values.

*Laulima* — Cooperation, many hands or people working together on a task to accomplish a goal

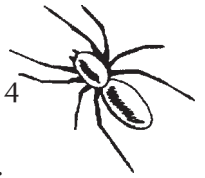
- Large numbers of wood ants feeding on caterpillars and moths ensures success.
- Termites can repair tremendous damage to their home because so many work together.
- Kenyan raid ants bunch together before invading a termite nest, combining the force of numbers with organized aggression.
- Herdsman ants form living bridges over gaps. The moving colony crosses these bridges.
- Millions of driver ants act like a super-organism, killing almost everything in its path. Ants release those trapped in slug slime, and several ants work together to carry heavy loads back to the nest.

*‘Ohana* — Extended family system, the primary component of society. Individual interests are not as important as the interests of the group.

- Living in family groups has been the key to cockroach success. They digest food only with the assistance of small organisms in their guts. These are passed from parent to offspring during feeding.
- All ants belong to extended families and carry prey home to share.
- Raising many close sisters together ensures success for the whole colony. Individual ants can afford to risk their lives since they will soon be replaced.
- Desert ant workers may die after only a few days in the scorching heat, but when they do find food they carry it immediately back to the nest.
- Leaf cutter ants are “robots,” programmed to serve the colony.

*Kuleana* — Responsibilities and roles. If each member of society fulfills their *kuleana*, all needs for survival will be met.

- When their nest is damaged, soldier termites come out first to defend, then workers come out to repair.
- Worker ants are dedicated to caring for the eggs, grubs, and cocoons of their younger sisters.
- Male ants die soon after mating, and the newly mated queens establish new colonies.
- During times of plenty, honeypot ants are filled by their sister workers with sweet food to eat during lean times.
- When driver ants go foraging, soldiers guard the column, cut up prey, form living bridges for other ants to cross, and hold back obstacles along the trail. Workers clear the trail and carry prey back to the nest. Other workers throw out “garbage” from the nest.
- Thousands of herdsmen ants link legs to form a living cradle that serves as the colony’s nest.



Write at least two similarities and two differences between Argentine ants and other ant species on the video. Here are six areas of comparison to use for ideas. There are others, as well.

**Argentine Ant Characteristics and Behaviors**

- Argentine ant colonies reproduce by “budding.” The new queens walk to their new nest site after having mated in the nest. Argentine ant males die after mating.
- Argentine ants are voracious predators.
- Argentine ants do not have permanent nests. They may move the entire nest from time to time.
- Argentine ant nests have more than one queen.
- Argentine ants do not defend their nests from other Argentine ants in the same area.
- Other

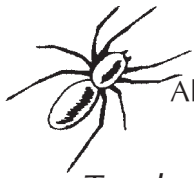
**Note Two Similarities and Two Differences Between Argentine Ants and Other Ant Species**

**Similarities**

- Wood ants are voracious predators during the summer.
- Kenyan raid ants are also predatory, pursuing termites and raiding their nests.
- Driver ants are particularly voracious predators, forming rivers of ants from which very little escapes alive.
- Driver ants move their nests frequently (in search of food).
- Herdsman ants regularly move their nests.

**Differences**

- Harvester ants in Arizona reproduce through mating flights. Tens of thousands of winged males and future queens from many colonies gather in an “ant orgy.” The mated females fly off to form new colonies.
- Malaysian herdsman ants get all their food from honeydew produced by bugs that they tend.
- Certain ants in South America make their homes in the hollow stems of a plant that also produces white nodules that serve as food for the ants. In return, the ants defend the plant against predators.
- In the Amazon, some ants grow hanging gardens in nests of chewed plant fibers.
- The ancestral piles of wood ants are passed through generations. Some may date back to the 1900s.
- Leaf cutter ant colonies, numbering two to three million workers, have a single queen.
- Honey pot ants defend their nests and prey against ants from other nests. Entire colonies may be overrun and the honeypots dragged off to the victorious colony.



*Teacher Version*

## Argentine Ants Quiz

- 1) Explain Argentine ants' response to a disturbance in their environment, such as a vibration, change in weather, or a manipulation of their nest.

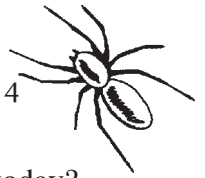
Answer should be based on this excerpt from the text:

Even a slight disturbance such as a vibration or a small manipulation of the nest will send Argentine worker ants scurrying away from the nest trying to carry larvae and pupae (their “brood”) to a safer place. Entire colonies may move in response to physical disturbance, changes in weather conditions, or changes in their food source.

Argentine ants are so sensitive that even a hiker or picnicker walking by or sitting down could create enough of a vibration or disturbance to cause a nearby nest to relocate.

- 2) How could this type of response help Argentine ants “hitch a ride” with humans?

It would take no more than a few ants and their cargo of brood to relocate into a hiker's pack, a picnicker's cooler or garbage bag, shipments of nursery stock, or other items. Once they have reached their new destination, they might be able to establish a new colony.



- 3) How many different populations of Argentine ants are known in Haleakalā National Park today?

Two

- 4) Is the size of those populations getting bigger, getting smaller, or staying about the same?

Both are getting larger.

- 5) Give two reasons why Argentine ants are considered a threat to native insects and plants in Haleakalā National Park.

Responses should be based on the following points from the text:

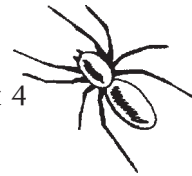
There are no native ants on the Hawaiian Islands, so most of the insects that evolved here are not adapted to defend themselves against the aggressive predatory abilities of large colonies of Argentine ants. Native Hawaiian insects are often soft-bodied and flightless—easy prey for the Argentine ant.

Argentine ants also may prevent native insects from using rocks, logs, and other objects for cover. These ants often nest under objects of this type. In the extreme environment of the alpine/aeolian zone, that cover may be important refuge to the native insects to shelter them against the midday sun, the nighttime cold, and the wind.

Argentine ants reduce the populations of native arthropod species. The effects are especially severe at higher elevations, where the prey species are fewer in number. Species that are known to be severely affected by Argentine ant predation in the park include native bees and moths, which are the main pollinators for native plants such as the silversword.

Argentine ants have no predators, competitors, or parasites in the alpine/aeolian ecosystem.

Argentine ants are well known for displacing native insect and ant species elsewhere in the world. Researchers and resource managers at the park are concerned that the same thing could happen at Haleakalā.



# That Ant is a Tramp

In 1967, scientists identified a new species of ant in Haleakalā National Park: *Linepithema humile*, the Argentine ant. This ant is thought to be native to Argentina and Brazil. Like every other ant species on the Hawaiian Islands today, it is an alien species. There are no native ant species here, although as you quickly learn if you leave food out at home, there are now plenty of ants around.

Most of the ants found on Maui and the other Hawaiian Islands cannot survive at the higher elevations of Haleakalā National Park. In fact, only two ant species other than the Argentine ant have been found above 2000 meters (6560 feet) within park boundaries. Neither of the other two species seem to pose a threat to the native plants, animals and insects of the alpine/aeolian zone of Haleakalā. But Argentine ants do.

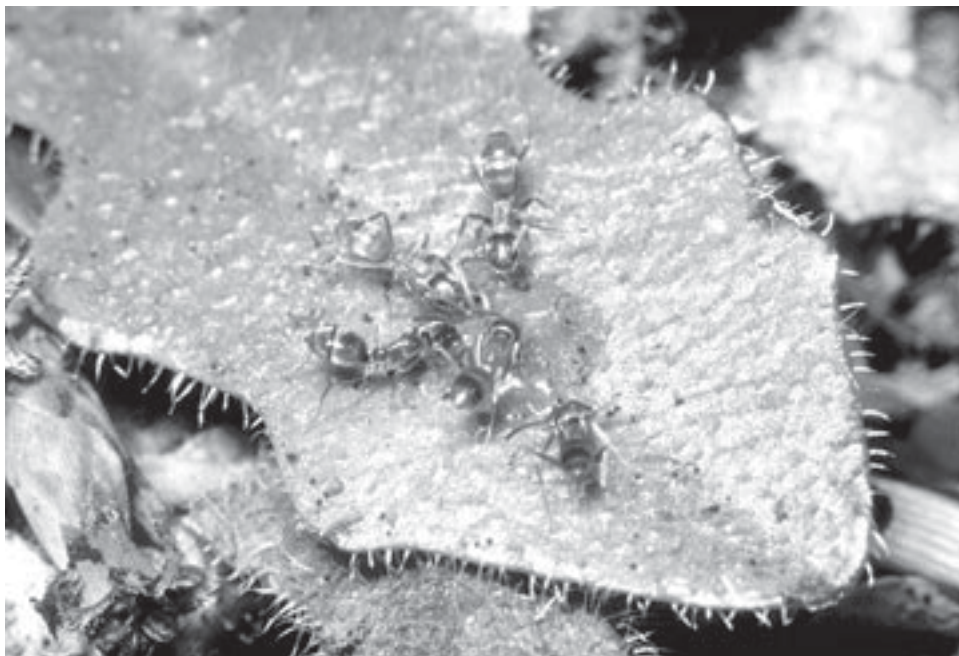
Before we get into that part of the story, however, let's take a step back in time and look at the spread of Argentine ants in Hawai'i.

## Argentine Ants Find a New Home

The Argentine ant probably established its presence in Hawai'i because of military activity. In 1940, it was discovered at Fort Shafter in Honolulu. There were several established colonies by that time. By 1949, the ants had spread beyond the confines of Fort Shafter. By that time, there was no looking back for the Argentine ant, which has since spread to all of the major Hawaiian Islands except Molokai. Even though Argen-

tine ants first established their Hawaiian presence on O'ahu, they are no longer found there. They are believed to have been out-competed by another introduced species, the big-headed ant (*Pheidole megacephala*).

By 1950, Argentine ants had reached Maui, where they were reported in Makawao. And in



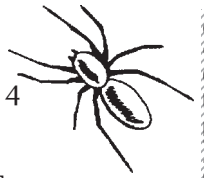
Argentine ants (Photo: Neil Reimer, U.S. Department of Agriculture)

1967, the first Argentine ant was identified in Haleakalā National Park.

How did the Argentine ant get to the park? It did not fly. It was not carried there in the digestive system of a bird or a pig. Most probably, Argentine ants traveled to their new home on Haleakalā with people who did not even suspect that they were carrying such an aggressive intruder with them.

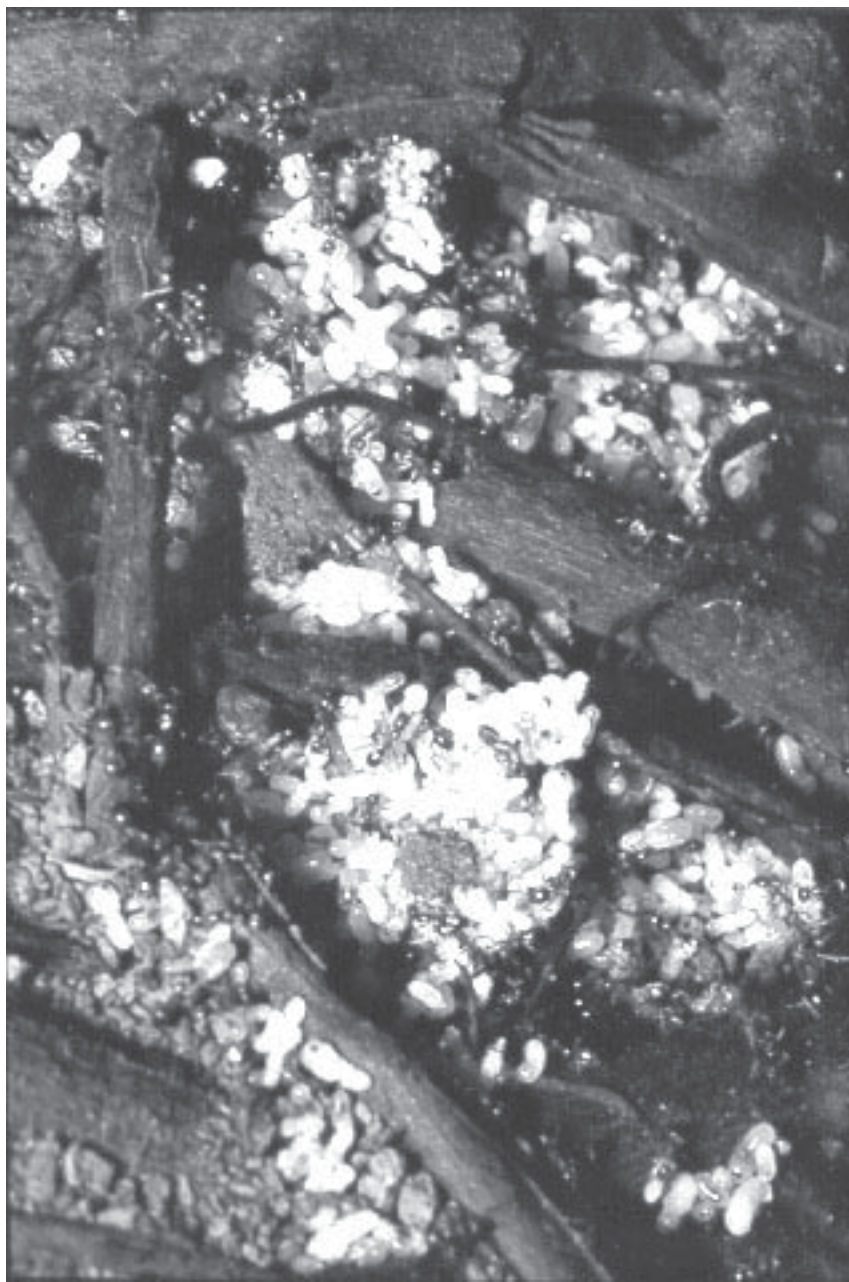
## The Biology and Behavior of a Tramp

Argentine ants are one of several species of ants that have come to be called "tramp species." They



are well adapted to living in close association with humans and are easily dispersed around the world as we ship goods and travel from one place to another.

One reason that tramp ants have been so successful at thriving in close proximity to humans is that they are well adapted to a changing environment. Human activity tends to create an unstable environment—one that is prone to change as we move things around, clear land, do landscaping, and go about other daily activities.



*Argentine ant nest (Photo: Ellen VanGelder)*

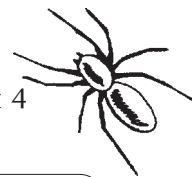
Tramp species are extremely mobile. Even a slight disturbance such as a vibration or a small manipulation of the nest will send Argentine worker ants scurrying away from the nest trying to carry “larvae” and “pupae” (the early developmental stages that constitute an ant colony’s “brood”) to a safer place. Entire colonies may move in response to physical disturbance, changes in weather conditions, or changes in their food source.

Argentine ants are so sensitive that even a hiker or picnicker walking by or sitting down could create enough of a vibration or disturbance to cause a nearby nest to relocate. If a few ants and their cargo of brood were to relocate into the hiker’s pack or the picnicker’s cooler or garbage bag, they could easily be transported to an uninfested area of the park. Once there, they could establish a new colony.

The rapid-response movement combines with other features of Argentine ant biology to make it a successful hitchhiker. These characteristics are shared among most tramp ant species.

### Polygyne Colonies

These ants are “polygyne.” In other words, each nest has more than one queen—one estimate is that there are typically one to 1.6 queens per 1,000 worker ants. Smaller queens sometime forage with worker ants. If a queen and some workers become hitchhikers together, they may be able to start a new colony in an uninfested area.



## A Brief Look at Ant Society and Reproduction

Most ants in a colony are wingless, infertile female workers. They do the labor that keeps the colony alive, including defense, foraging, and brood-tending.

Ant queens are the only female ants that can reproduce. A queen mates once in her life, storing all the sperm from that mating in her body and using it as needed during the course of her reproductive life.

Ant males are produced only to mate. After mating, they die.

The difference between ant worker larvae and queen larvae is not in the genetics of the eggs they come from. Larvae are “differentiated” into these castes based on what they are fed and when. The development of male ants also depends on feeding. Ant workers feeding their “brood” of eggs, larvae, and pupae respond to environmental signals such as food availability and the presence or absence of pheromones (scent signals) from a queen.

If the queens are removed from an Argentine ant colony, worker ants respond by producing new males and queens from existing larvae. They do this through changes in feeding.

## Colonies Reproduce by Budding

Unlike queens of many other ant species, Argentine ant queens and males do not fly from the nest at mating time. The colonies reproduce by “budding.” Mating happens within the nest, and the new queens leave the nest on foot to establish a new nest close by. Like other tramp ants, Argentine ant populations spread outward from a single point. Unless, of course, the ants hitch a ride.

## Unicolonial Populations

Argentine ants are “unicolonial.” In other words, they form large colonies of many different nests. Unicolonial species do not exhibit aggressive behavior toward other ants from different nests in the same area. This non-competitive behavior allows Argentine ants and other tramp species to establish very large, high-density colonies. The sheer numbers of these ants, along with the aggressiveness of their workers, allows them to effectively prey upon and/or outcompete many

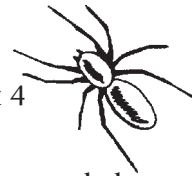
other species of ants and insects. Since Argentine ants are most often imported and not native, this ability allows them to dominate the areas they invade. In Argentine ant-infested areas, other species of ants and insects may be virtually eliminated.

## What Makes Argentine Ants a Potential Threat to Native Insects and Plants on Haleakalā?

There are no native ants on the Hawaiian Islands, so most of the insects that evolved here are not adapted to defend themselves against the aggressive predatory abilities of large colonies of Argentine ants. Native Hawaiian insects are often soft-bodied and flightless—easy prey for the Argentine ant’s ground forces. Argentine ants are voracious feeders and other insects are only one item on their wide-ranging menu.

In addition to preying on native insects, Argentine ants also may prevent these natives from





using rocks, logs and other objects for cover. These ants often nest under objects of this type. In the extreme environment of the alpine/aeolian zone, that cover may be important refuge to the native insects to shelter them against the midday sun, the nighttime cold, and the wind.

In Haleakalā National Park, researchers who surveyed native “arthropods” in ant-infested areas and non-infested areas found that the ants reduce the populations of native species. (Arthropods are a group of invertebrate animals with jointed bodies and limbs that includes insects, spiders, scorpions, mites and centipedes.) The effects are especially severe at higher elevations, where the prey species are fewer in number. Species that are known to be severely affected by Argentine ant predation in the park include native bees and moths, which are the main pollinators for native plants such as *‘āhinahina*.

Another advantage Argentine ants have is that there are no predators, competitors, or parasites in the alpine/aeolian ecosystem. Argentine ants are well known for displacing native insect and ant species elsewhere in the world. Researchers and resource managers at the park are concerned that the same thing could happen at Haleakalā.

## How Are the Ants Spreading in the Park?

Since the first Argentine ants were found in Hosmer Grove in 1967, the ants have expanded their territory each year, spreading steadily outward through the budding process described above. In 1982, a second population of Argentine ants was discovered in the park, at the parking lot at Kalahaku Overlook, further up the mountain.

Given the Argentine ant’s tendency to hitch a ride with humans, it is not surprising that the first population found in the park was near Hosmer Grove, a picnic area and campground that receives a lot of visitors. Likewise, Kalahaku Overlook is frequented by large numbers of people.

Just over thirty years after it was first recorded in the park, the Argentine ant range has expanded to over 500 hectares (1200 acres, or about two square miles). That is about 4.5 percent of the entire area of the park. Researchers believe that much of the “crater” at Haleakalā could be inhabited by Argentine ants eventually, if no way is found to control their spread. According to one analysis, approximately 50 percent of the area of the park—including the west slope of the volcano and most of the western and central parts of the crater—is potential Argentine ant habitat.

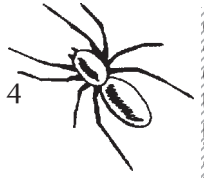
## Sources

Fellers, J. H. and G. M. Fellers, “Status and distribution of ants in the Crater District of Haleakala National Park,” *Pacific Science*, Vol. 36, 1982, pp. 427-437.

Krushelnycky, P. D., et al, *A Thirty Year Record of Argentine Ant Range Expansion in Haleakala National Park, Maui, Hawaii*, U.S. Geological Survey, Biological Resources Division, Makawao, Hawai‘i, in preparation.

Krushelnycky, P. D. and Joe, S., *HNIS Report for Linepithema humile, Hawaiian Ecosystems at Risk Project*, March 1997.

Passera, L., “Characteristics of Tramp Species” in *Exotic Ants: Biology, Impact, and Control of Introduced Species*, D. F. Williams (ed.), Westview Press, 1994.



# Ants Video Note Sheet

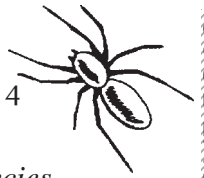
Write notes based on what you learn watching *Ants! Little Creatures Who Run the World*.

*Write something you learned from the video about ants, termites, or other social insects that illustrates each of these traditional Hawaiian values.*

*Laulima* — Cooperation, many hands or people working together on a task to accomplish a goal

*‘Ohana* — Extended family system, the primary component of society. Individual interests are not as important as the interests of the group.

*Kuleana* — Responsibilities and roles. If each member of society fulfills his or her *kuleana*, all needs for survival will be met.



Write at least two similarities and two differences between Argentine ants and other ant species on the video. Here are six areas of comparison to use for ideas. There are others, as well.

<b>Argentine Ant Characteristics and Behaviors</b>	<b>Note Two Similarities and Two Differences Between Argentine Ants and Other Ant Species</b>
<ul style="list-style-type: none"><li>• Argentine ant colonies reproduce by “budding.” The new queens walk to their new nest site after having mated in the nest. Argentine ant males die after mating.</li><li>• Argentine ants are voracious predators.</li><li>• Argentine ants do not have permanent nests. They may move the entire nest from time to time.</li><li>• Argentine ant nests have more than one queen.</li><li>• Argentine ants do not defend their nests from other Argentine ants in the same area.</li><li>• Other</li></ul>	



# Argentine Ants Teaching Teams Background

## Topic #1: The Location and Spread of Argentine Ants in Haleakalā National Park

### Where Are the Argentine Ants?

[See Figure 1: Argentine Ant Populations in Haleakalā National Park, 1997, p. 28.]

Argentine ants were first found in the park at Hosmer Grove in 1967. Since then, the ants have expanded their territory each year, spreading steadily outward through the budding process described in the next section. In 1982, a second population of Argentine ants was discovered in the park, at the parking lot at Kalahaku Overlook, further up the mountain.

Just over thirty years after it was first recorded in the park, the Argentine ant range has expanded to over 500 hectares (1200 acres, or about two square miles). That is about 4.5 percent of the entire area of the park.

The lower elevation population is located southwest (leeward) of Hosmer Grove picnic and camping area, the original site of introduction at 2074 meters (6803 feet). This population is in native subalpine shrubland.

The upper elevation population was first discovered at Kalahaku Overlook at 2775 meters (9102 feet). Vegetation at this site is much more sparse, as in the alpine/aeolian ecosystem. This population has expanded primarily down the crater wall to the “crater” floor, and is now advancing across the “crater” floor.

### How Far Could They Spread?

[See Figure 2: Potential Range of the Argentine Ant in Haleakalā National Park, p. 29.]

Based on patterns in range expansion over the past 30 years, researchers believe it is likely that the Argentine ant is capable of colonizing large

parts of the park’s subalpine shrubland and aeolian zones.

Researchers have estimated the potential range of the Argentine ant within the park, taking into account rainfall, elevation, and habitat suitability (including nest site availability, vegetative cover, and estimated levels of food resources such as arthropods and nectar or honeydew sources). This predicted potential range covers the west slope and most of the west and central “crater.” If Argentine ants spread to this whole range, they would occupy nearly 50 percent (5500 ha or 13,585 acres) of the park’s total area.

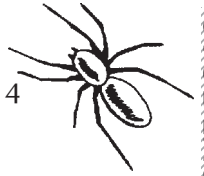
This estimate does not account for the potential range outside of park boundaries, as you can see on the map.

### How Quickly Are They Spreading?

[See Figure 3: Spread of the Lower Population, p. 30 and Figure 4: Spread of the Upper Population, p. 31.]

The two populations of Argentine ants are expanding at different rates.

**Lower population:** The first surveys of ant distribution were done in the early 1980s, more than ten years after the ant was found at Hosmer Grove. The population’s rate of radial spread (expansion of the population boundaries outward from a central point) since 1982 has averaged approximately 29 meters/year.



Upper population: Expansion of this population has been much more dramatic, with spread exceeding 150 meters/year in some areas.

- For the first seven years in which this population was monitored, it spread roughly equal distances in all directions at a rate of approximately 24 meters/year.
- By 1993, westward spread continued at this pace, but the rate of spread toward the east had increased to about 81 meters/year, bringing the upper population to the “crater” floor.

- From 1993 to 1997, peak rates of spread (exceeding 150 meters/year) occurred at lower elevations in the crater. The population spread more slowly (23 meters/year) at the higher elevations west of Kalahaku Overlook on the “crater” rim.

Note: On Figures 3 and 4, “pitfall sites” are indicated. Pitfall sites are the location of traps used to assess population numbers.

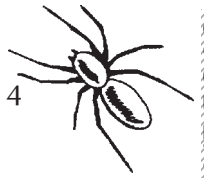
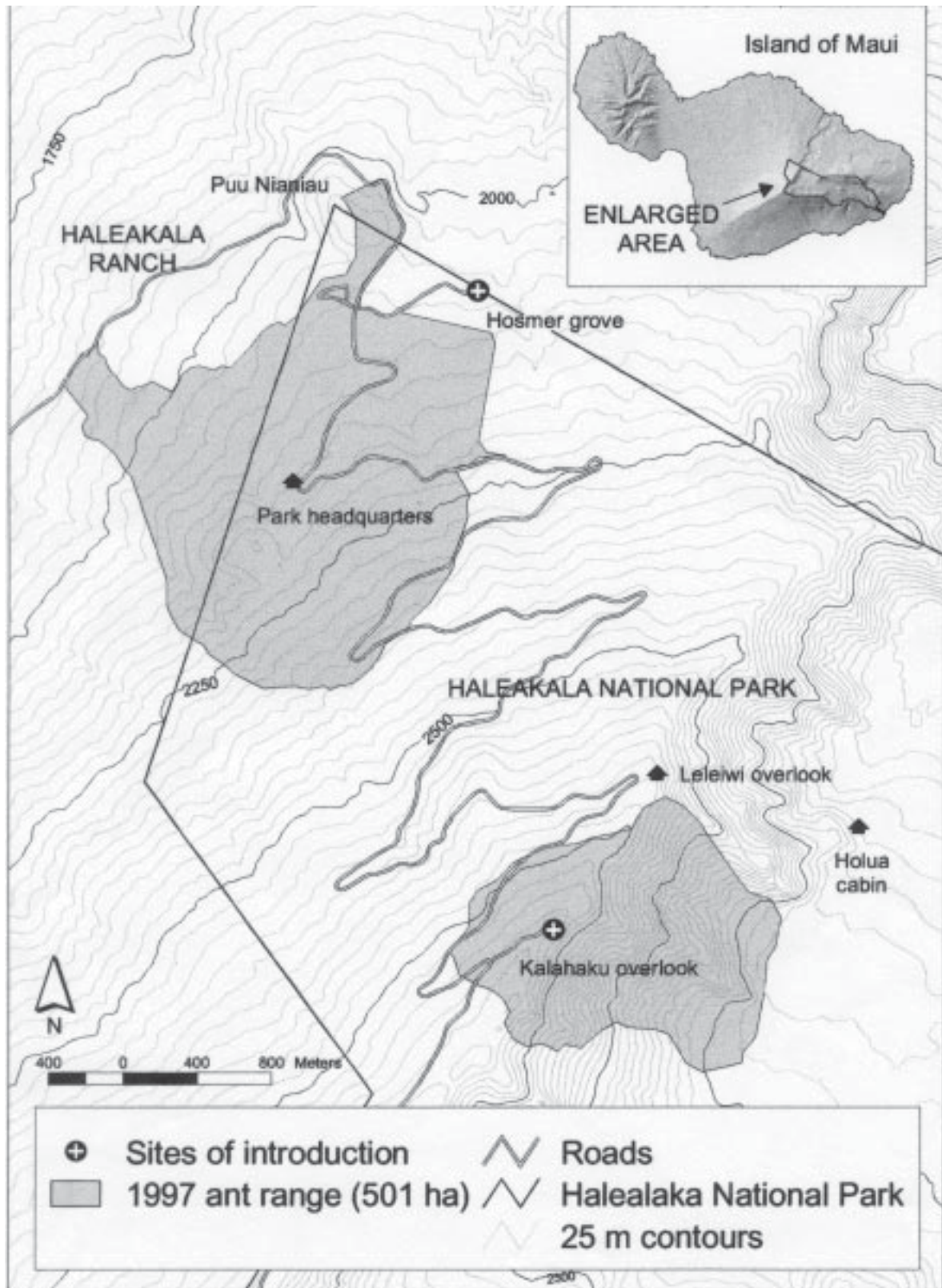


Figure 1: Argentine Ant Populations in Haleakalā National Park, 1997



Map: Krushelnycky, Paul, S. Joe, Lloyd Loope, and Arthur Medieros, unpublished data.

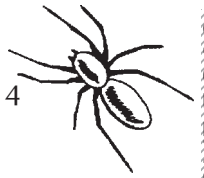
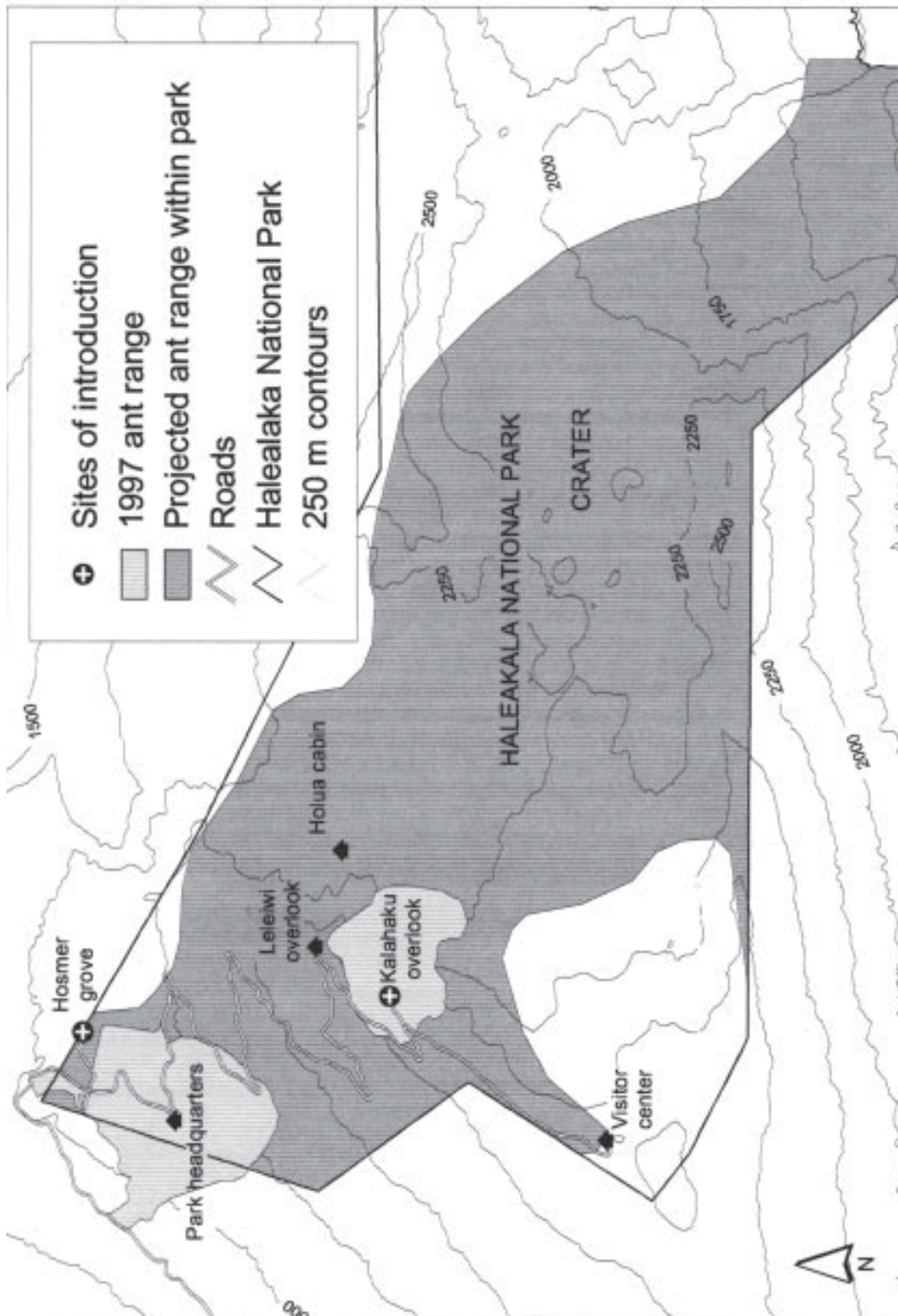


Figure 2: Potential Range of the Argentine Ant in Haleakalā National Park



Map: Krushelnycky, Paul, S. Joe, Lloyd Loope, and Arthur Medieros, unpublished data.

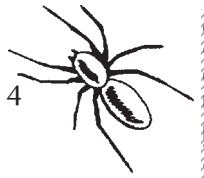
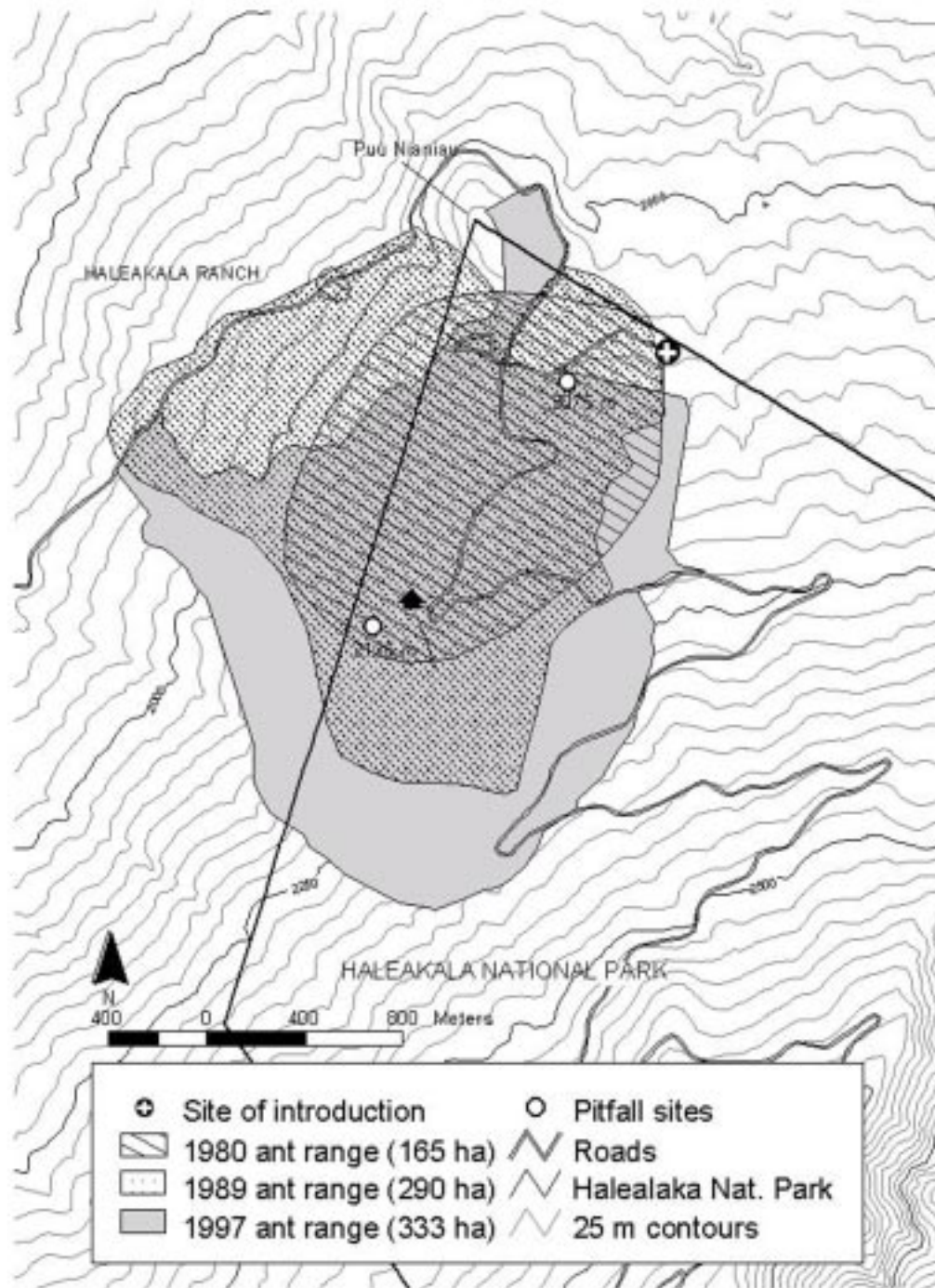


Figure 3: Spread of the Lower Population (1997 range projected)



Map: Krushelnycky, Paul, S. Joe, Lloyd Loope, and Arthur Medieros, unpublished data.



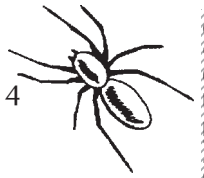
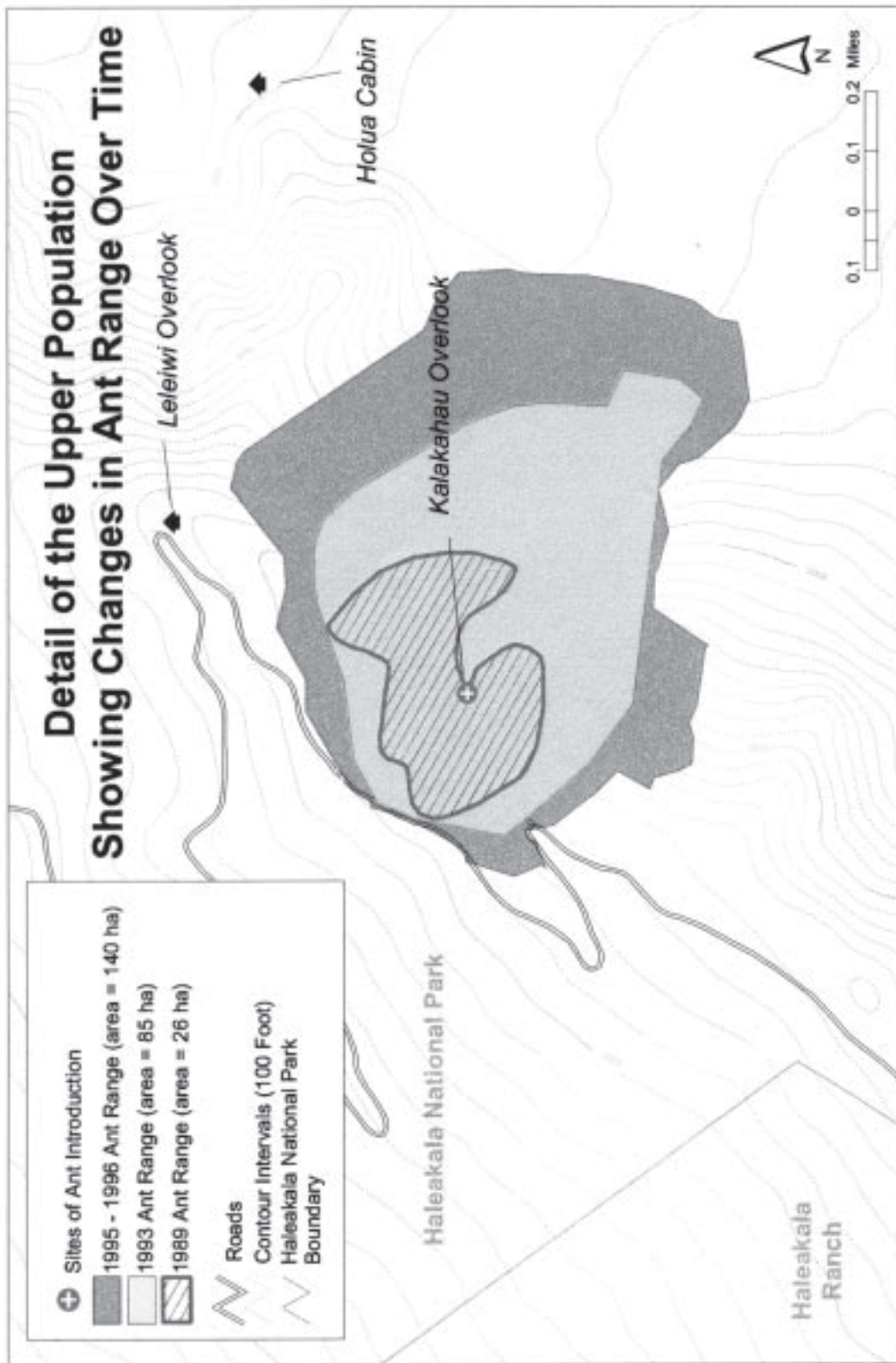


Figure 4: Spread of the Upper Population



Map: Krushelnycky, Paul, S. Joe, Lloyd Loope, and Arthur Medieros, unpublished data.



# Argentine Ants Teaching Teams Background

## Topic #2: The Threat Argentine Ants Pose to Native Arthropods in the Alpine/Aeolian Ecosystem

In 1985 and 1986, researchers did a study to determine the impact of the Argentine ant on the native ground-dwelling “arthropods.”

(Arthropods are a group of invertebrate animals with jointed bodies and limbs that includes insects, spiders, scorpions, mites and centipedes.)

Researchers used two techniques in this study: “pitfall traps” and “under-rock surveys.” They set up two study sites within the Argentine ant range and two outside of it.

The “pitfall traps” were specimen jars and baby food jars partially filled with an antifreeze solution to preserve trapped organisms. The inside rim of each jar was baited with finely blended salted fish. These traps were buried flush with the ground surface where they attracted foraging invertebrates that fell into the preservative in pursuit of the bait. After two weeks, the jars were removed and the contents sorted and identified in a lab.

The under-rock surveys provided additional information. From plots within the study site, researchers lifted rocks and catalogued the invertebrates they found under the rocks. The under-rock surveys provided information about some types of invertebrates that were unlikely to be caught in pitfall traps (because of their food source preferences, for example).

The study suggests that many native arthropod species are negatively affected by the presence of the Argentine ant. Other invertebrate species are positively affected, while still others do not seem to be affected one way or the other. Here are the native species the study suggests are most negatively affected by the Argentine ant.

- Large Lepidopteran larvae (the young of one of the endemic noctuid moth species)
- *Nesoprosope* larvae (the young of the endemic Hawaiian yellow-faced bees).  
The study suggests that ants destroy the nests this ground-dwelling bee builds under rocks and feeds on the larvae.
- Carabid beetles
- Spiders including *Lycosa hawaiiensis*, the endemic wolf spider.

[See the following pages for informational cards about the native arthropods mentioned above.]

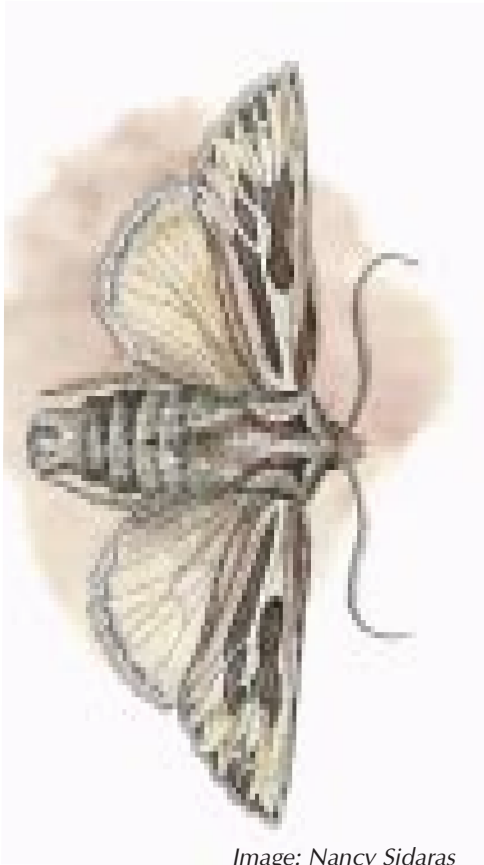
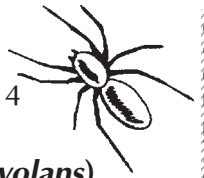


Image: Nancy Sidaras

### Hawaiian Noctuid Moth (*Agrotis arenivolans*) Order Lepidoptera, Family Noctuidae

**Status** Endemic to Hawai'i.

**Habitat** •Larvae have been seen feeding on the leaves of the native shrubs *pūkiawe* and *na'ena'e*. They also feed on the seeds of the *'āhinahina*.  
•Caterpillars burrow in cinders during the day and feed at night.

**Characteristics** •Adults have a layer of long, thick hairs on their wings and bodies that help keep them warm, reflect sunlight and prevent water loss.  
•Adult noctuid moths visit flowers at night, probably acting as pollinators for native plants.

**Think about it:** Noctuid larvae are abundant in the alpine/aeolian zone. But wherever the Argentine ant is established, very few of these caterpillars can be found. What do you think is happening?

**Did you know?** The larvae (caterpillars) of most Lepidoptera species around the world feed on plants. But the larvae of at least one Hawaiian noctuid moth species in the alpine/aeolian zone feed on other arthropods as well as on the leaves of the few plants that occur in the area. Their arthropod prey is either dead or in a stupor from the cold night air.



Image: Nancy Sidaras

### Hawaiian Yellow-Faced Bee (*Nesoprosopis [Hylaeus] volcanicus*) Order Hymenoptera, Family Colletidae

**Status** Endemic to Haleakalā.

**Habitat** Lays eggs in a winding, silken tube nest, usually under a rock.

**Characteristics**

- Solitary, unlike the social honeybee that lives in cooperation with other bees.
- Visits flowers to gather pollen and nectar to feed its young.
- Small—only 6-12 mm (.024-.048 in) long.

**Think about it:** Why would these small bees be so critical to the pollination of many native plants including *pūkiawe* and the *'āhinahina*?

**Did you know?** Another species of Hawaiian yellow-faced bee (*N. volatilis*) found in the alpine/aeolian zone is a nest parasite. It lays its eggs in the nest of *N. volcanicus* or the related *N. nivalis*. It may visit flowers, as well, but only to gather nectar to feed itself.

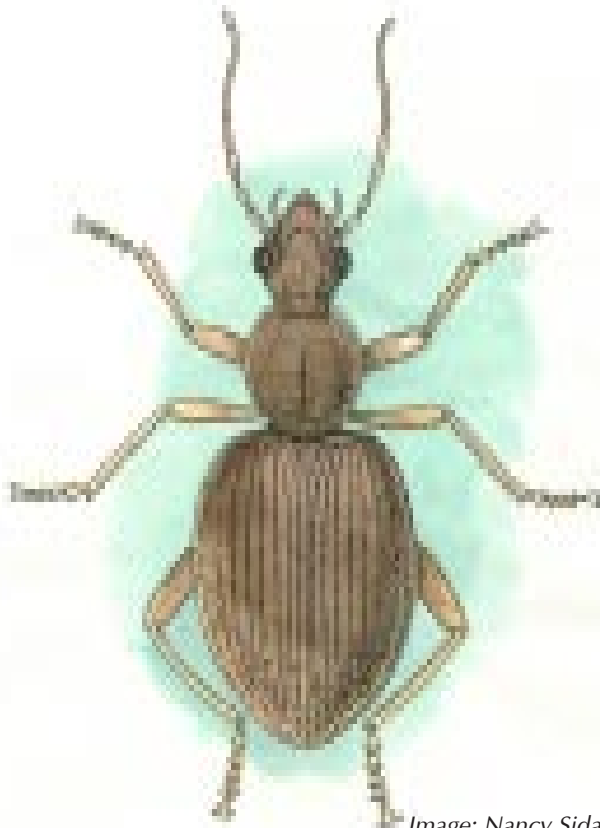


Image: Nancy Sidaras

## Carabid Beetle (or Ground Beetle) (*Mauna frigida*)

Order Coleoptera, Family Carabidae

**Status** Endemic to Haleakalā. Of ten carabid beetle species recorded within the alpine/aeolian zone, nine are endemic to Haleakalā.

**Habitat** Five of the endemic carabid beetle species, including *Mauna frigida* have been found only on the upper 150 meters (492 feet) of the mountain's summit.

### Characteristics

- These five species are flightless scavenger-predators.
- Thick exoskeletons protect them from water loss and extreme cold.

**Think about it:** These five species are extremely rare. Little is known about their current status or biology. Some of them may be extinct. How would you go about trying to find out?

**Did you know?** The 215 Hawaiian endemic carabid beetle species probably evolved from as few as six original immigrants.

## Wolf Spider (*Lycosa hawaiiensis*)

Order Araneae, Family Lycosidae

**Status** Endemic to Haleakalā.

### Habitat

- Live only at or near the mountain's summit
- Makes shallow burrows under rocks by cementing windblown leaves and other detritus together with silk. The burrows protect it from the cold, dry climate.

### Characteristics

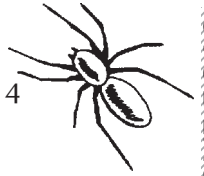
- Normally dark in color, turns silver when hunting among the 'āhinahina rosettes.
- A predator-scavenger that hunts on the ground rather than building web.
- A large spider, measuring between 3.5-5 cm (1.4-2 in) in length.

**Think about it:** How might a dark-colored body and long legs help a wolf spider survive in the cold temperatures of the alpine/aeolian zone?

**Did you know?** Mother wolf spiders carry silk egg sacs (larger than their own bodies) beneath them. As the young hatch, they ride on their mother's back while she hunts.



Photo: Haleakalā National Park



# Argentine Ants Teaching Teams Background

**Topic #3: Biological and Behavioral Characteristics That Make Argentine Ants a Strong Invader**

and

**Topic #4: Characteristics of Argentine Ants That Affect How They Spread and Can Be Controlled**

[For more information about these topics, see the Student Page “That Ant Is a Tramp.”]

Because of the constant expansion of this species and its potential to seriously deplete endemic arthropod species (including essential pollinators for native plant species including the silversword), park researchers and resource managers began looking for a way to keep the ants from spreading to new areas.

Several basic biological and behavioral characteristics of the Argentine ant suggest that it would be vulnerable to a control strategy that uses toxicants (poisons). In brief, here are four of these characteristics and what that means for designing a control program:

## 1) Polygyne Colonies & Flightless Queens Disperse by Budding

These characteristics usually go together.

- “Polygyne” colonies have many queens.
- “Budding” is a process by which new queens will locate their new nests near their birth colony—usually within meters. Mating takes place within the birth nest. Afterward, along with a few workers from her birth nest, the new queen walks away to a new site and begins her own nest. She lays eggs and the workers that accompanied her in her relocation do the work of digging the nest and tending the brood.

This suite of characteristics is crucial to designing a control program. With Argentine ants, it is

possible to treat the boundaries of the population to keep it from spreading further. This is because of the budding process through which the population expands slowly outward. A new, noncontiguous population will only be established if people transport the ants to a new place.

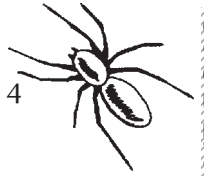
## 2) Unicolonial and Non-competitive

Argentine ant workers are not territorial. In other words, they do not defend territories against ants of the same species. In fact, workers born elsewhere are readily accepted into the nest. Workers often wander between nests, helping out in whatever nest they happen to be in at the time. New queens that disperse from their birth colony may also be accepted into an existing nest.

Because workers move around so readily and move the nest contents at the slightest disturbance (see the Student Page “That Ant is a Tramp” for more detail about this) there is no well-defined colony. It is often impossible to distinguish between nests. This is called a “unicolony.” The population is essentially one large colony with high densities of ants. These high-density colonies often dominate their habitat and usurp other ground-dwelling arthropods.

This set of characteristics has two major impacts on a control program:

- i) There is no way to control the Argentine ant population one nest at a time; and
- ii) Argentine ants respond in large numbers to introduced baits. In areas of high ant



densities, researchers believe ants will quickly take most of the bait back to their nests, leaving little behind for whatever non-target species are left in the area. If that is true, the use of toxicants combined with bait is likely to have maximum impact on the Argentine ants and minimal impact on other species.

### 3) Seasonal Food Preferences

Argentine ants prefer different food types at different times of the year. During the summer, they are attracted to protein-based baits. During the winter, the same baits are much less effective. This characteristic is important for determining what time of year to treat using a particular bait. It is also a good reason to do a year-long bait preference test.

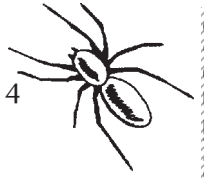
### 4) Trophallaxis

“Trophallaxis” is a process by which regurgitated food is passed among colony members. Food is exchanged in this way between workers, from workers to brood, and from workers to queens. The process of trophallaxis within ant colonies allows food to be passed quickly through the nest. This process is typical of most ant species.

In designing a control program aimed at eradicating ants, it is important that the workers pass on the toxicant to other ants, especially the queen, so the whole colony is poisoned and cannot repopulate itself. Since workers are the first to eat the food (then pass it on to others through trophallaxis) the toxicant needs to be slow acting, so workers have a chance to pass it on before they die. Combining a slow-acting toxicant with a highly attractive bait is a key to success.

### In Contrast to the Argentine Ant...

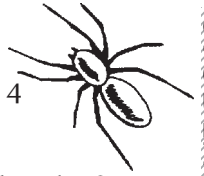
- Many ant species have “monogyne” (single queen) colonies. Tramp species often have the polygyne colony type.
- Many ant species disperse by a process in which new queens go on a “nuptial flight” or mating flight along with winged males. In these species, the new nest can be kilometers away from the new queen’s birth colony. The males die after mating, and the new queen has not been accompanied by any workers. She digs a hole in the ground and seals herself in. She raises the first brood of workers by herself and feeds them off her fat reserves. When these workers are born, they take over the work of the nest (gathering food, maintaining the nest, tending the brood, etc.) and the queen continues laying eggs.
- In species whose queens disperse by flight, new populations can be established far away from the original colony and are difficult to track.
- For many ant species, the nest and the colony are the same. The colony is distinct from other colonies.
- Colony workers in many ant species are territorial. They defend the area from all other ants, including ants of the same species from other colonies.
- Most ant species are “multicolonial.” A population of these ants is made up of many separate colonies. One common control method is to exterminate an individual colony, for example by dousing the nest with a liquid that kills ants on contact.



# Argentine Ants Quiz

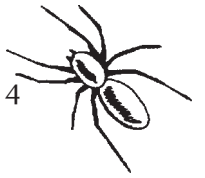
- 1) Explain Argentine ants' response to a disturbance in their environment, such as a vibration, change in weather, or a manipulation of their nest.

- 2) How could this type of response help Argentine ants “hitch a ride” with humans?



- 3) How many different populations of Argentine ants are known in Haleakalā National Park today?
  
  
  
  
  
  
  
  
  
  
- 4) Is the size of those populations getting bigger, getting smaller, or staying about the same?
  
  
  
  
  
  
  
  
  
  
- 5) Give two reasons why Argentine ants are considered a threat to native insects and plants in Haleakalā National Park.
  - i)
  
  
  
  
  
  
  
  
  
  
  - ii)





Activity #3

# Controlling the Argentine Ant

## ● ● ● Class Period One *Argentine Ant Control Efforts*

### Materials & Setup

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- Argentine ant range acetates (master, pp. 48-59)
- Overhead projector and screen

### For each student

- Student Page “Designing a Control Strategy That Works: Questions From the Discussion” (pp. 60-64)

### Instructions

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- 1) Ask students to review what they learned during the last activity about where and how quickly Argentine ant populations are spreading within Haleakalā National Park. Have students from the team that worked on that topic provide a quick synopsis.
- 2) Using Teacher Background “The Spread of Argentine Ants in Haleakalā National Park and Recent Efforts at Control” (pp. 40-43), lead a class discussion on recent efforts to control the spread of Argentine ants in Haleakalā National Park. Use the acetates to illustrate key points.
- 3) Assign the Student Page “Designing a Control Strategy that Works: Questions from the Discussion” as homework.

## ● ● ● Class Period Two *Effectiveness of Control Efforts*

### Instructions

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- 1) With the entire class, discuss students’ determinations about the effectiveness of the ant control experiment. Review their calculations and talk about factors that might make the results questionable.
- 2) Ask students to discuss the idea that current control efforts may be simply buying time during which alternative methods of *eradication* may be developed and tested.
- 3) Review the entire unit, discussing student questions and ideas.

### Journal Ideas

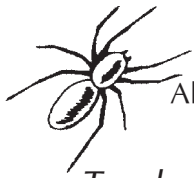
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- What can you do to prevent the spread of Argentine ants within Haleakalā National Park?
- What kind of educational program would be effective at helping park visitors learn about Argentine ants and how to stop their spread?

### Assessment Tools

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- Student Page “Designing a Control Strategy that Works: Questions from the Discussion” (teacher version, pp. 44-47)
- Participation in class discussion
- Journal entries



### Teacher Background

## Designing and Implementing an Argentine Ant Control Program

Because there are native ants in most natural areas around the world, few attempts have been made to control ants for conservation purposes. Researchers and resource managers in Haleakalā National Park face quite a challenge designing a control program for the Argentine ant. There is, however, a huge industry built around the control of ants in urban and agricultural situations and ongoing research about the effectiveness of various pesticides. Still, the number of ant control products is limited because the U.S. Environmental Protection Agency (EPA) has a strict registration process for pesticides. The EPA must separately register each product (which is a combination of an attractive bait and the toxicant or poison that actually kills the ants).

Recently, a toxicant called hydramethylnon has gained EPA approval for a variety of uses and has been found to be relatively effective against ants and much safer than many of its predecessors. Hydramethylnon was used in the late 1980s to eradicate the little fire ant (*Wasmannia auropunctata*) from Santa Fe Island in the Galapagos. So researchers began looking at options for using this pesticide against Argentine ants in the park. Here is how the control program evolved:

### Step #1: Conduct a Bait Preference Test

Because the park's infested area is large and most of it is inaccessible by foot, spreading the bait by helicopter is the most feasible approach to broad-scale treatment. This dispersal method requires using a solid, pelletized bait. So researchers conducted a year-long test to determine which baits the ants preferred.

### Step #2: Test the Combination of Bait and Toxicant on Small Plots

The most attractive bait was protein-based. So researchers did these tests during the summer when ant populations rise and bait retrieval is highest. During the summer, the ants' need for protein is the greatest.

Most ant-control strategies involve prolonged access to toxic bait. But the hydramethylnon formulated in the bait breaks down in the sunlight in only a few days. Researchers knew that spreading the toxic bait by helicopter over large areas would be an expensive proposition, unlikely to happen more than once a year. So they decided to test the effect of a single broadcast treatment of toxic bait, hoping for eradication, even though it seemed like a long shot.

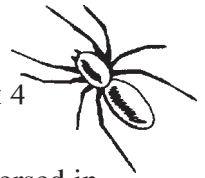
This test application did not achieve eradication. But it did result in a 97 percent reduction in the numbers of foraging ants.

### Step #3: Refine Approach to Focus on Control

Based on their test results, researchers decided that eradication would not be attainable but that controlling the spread of the populations would be possible. They hypothesized that applying the toxic bait along the borders of the ants' range would limit the population's expansion into new territory.

### Step #4: Test the Control Hypothesis

In this study, planned for the summer of 1996, they would measure the effect of treating the population borders. They chose two study sites, one in each of the two ant populations.



[See Acetate Figure 5: 1996 Aerial Treatment Plots, p. 52. If you want to review the location of the ant populations and their direction of expansion, see Acetate Figures 1-4, pp. 48-52.]

The plot in the upper population was located at the “crater” floor along the border expanding into the summit basin (the “crater plot”). It was a large plot, covering over 20 hectares. The location and size of this plot were chosen because researchers and resource managers wanted to:

- Try to halt the rapid spread into the “crater” and keep the ants away from a campground located less than 500 meters (1640 feet) from the ant boundary,
- Determine whether a deeper plot is more effective than a narrower plot, and
- Test the future possibility of treating large areas.

Six monitoring sites plus a control site were used to track the reduction and recovery of ants in the “crater” plot. Monitoring sites along the border in both the treated and untreated areas were used to measure the rate of expansion. [See Acetate Figure 6: Upper Population Plot, p. 53.]

The lower population plot (the “frontcountry plot”) was also located along an expanding border but was much smaller. It measured 260 meters (853 feet) long and only 120 meters (394 feet) deep. The design of this plot was chosen because:

- Researchers wanted to see if a narrow border treatment would be sufficient to stop movement, and
- It represents a small section of what would potentially be a 120-meter-wide swath encompassing all expanding ant boundaries.

Monitoring transects with bait stations every ten meters (33 feet) were established in the treated plot and in adjacent, untreated shrubland. These were used to measure rates of reinvasion in the treated plot, as well as rates of territory expansion. [See Acetate Figure 7: Lower Population Plot, p. 54.]

In August 1996, the toxic bait was dispersed in these two plots by a helicopter and a bait hopper. The bait hopper was designed and built especially for this purpose.

[See Acetate Figure 8: Post-Treatment Results for the Lower Population Plot and Upper Population Plot, p. 55.]

## Study Results

- Ant numbers in both plots dropped off soon after treatment.
- By November, the numbers in the upper plot had jumped back up to 50 percent of their pretreatment levels. As the winter months set in, population levels dropped off (as they do naturally—see the control figures in Figure 8 for comparison). In the upper plot, population levels began recovering from this seasonal trend in June and July of 1997.
- In the lower plot, there was very little recovery by November, and by July (10 1/2 months after treatment), the ant numbers had recovered to only 21 percent of their pretreatment levels.

## The Conclusions?

- The smaller, narrower frontcountry plot was more effective in suppressing recovery than the large “crater” plot. Researchers believe this is primarily due to the fact that it is easier for the helicopter pilot to cover narrower areas more thoroughly with the toxic bait.
- There was no expansion of the ants’ territory after treatment in either of the plots, while the borders in the untreated control areas expanded significantly.



### Stop Right Here!

Students will analyze what happened as a result of this treatment as part of their homework assignment. Use the remainder of the information on this sheet as background for the Class Period Two class discussion.

- The lower population expanded, on average, only one meter (three feet) beyond its pre-treatment range. This expansion is only about 3.5 percent of the mean expansion rate for previous years.
- Expansion on the western portion of the upper population was similar and was only about 4.5 percent that of previous years.

## Step #5: Treat All Expanding Borders

Based on these results, researchers decided to treat all expanding borders of both populations in a 120-meter-wide (394-foot-wide) swath to determine if this control strategy would work on a larger scale. In August of 1997, they treated the entire upper population border and the southwest edge of the lower population border.

[See Acetate Figure 9: Population Border Areas Treated During 1997, p. 56.]

They monitored expansion of the ant population at 84 stations along the treated borders. [See Acetate Figure 10: Lower Population Monitoring Sites, p. 57, and Figure 11: Upper Population Monitoring Sites, p. 58.]

### Treatment Results

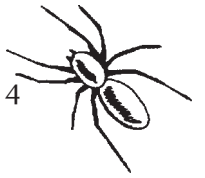
- The mean rate of expansion at these stations one year after treatment was considerably lower than mean rates of expansion calculated from distribution data for previous years. [Acetate Table 1: Comparison of Pre- and Post-Treatment Boundary Expansion, p. 59, shows the difference. Students will have calculated some of these figures in their homework assignment.]

### Different Kinds of Research

Here is a little twist that you may want to go into with students. It helps illustrate the difference between experimental and applied research.

During quarterly monitoring of the 84 stations after the aerial treatment, researchers were able to identify areas where the treatment was not working (perhaps due to pilot error or unknown ecological factors). In those small trouble spots, researchers applied the toxic bait again by hand. So, in reality, the method that worked to slow the spread of the ants was aerial treatment of a 120-meter-wide border coupled with periodic hand treatment of small areas.

If this were a purely experimental study, researchers would not have changed the parameters of the study by reapplying toxic bait by hand. However, since the ultimate goal is to achieve a resource management objective (controlling the spread of Argentine ants), the researchers could make adjustments as they went along.



- Expansion on the eastern portion of the upper population was greatest but still only about 25 percent of the 81 meters/year (266 feet/year) calculated for the 1993-1997 time period.

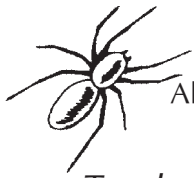
Given these results, researchers and resource managers plan to use the border treatment strategy each year to slow the spread of ants in the park. Their ultimate goal is still to eradicate the Argentine ant in the park. Slowing their spread is a way to buy some time to investigate and develop different approaches to eradication.

## Sources

Krushelnycky, P. D., et al, *A Thirty Year Record of Argentine Ant Range Expansion in Haleakala National Park, Maui, Hawaii*, U.S. Geological Survey, Biological Resources Division, Makawao, Hawai‘i, in preparation.

Loope, Lloyd L., Arthur C. Medeiros, and F. R. Cole, in *Proceedings of the Conference on Science in the National Parks, 1986, Volume 5: Management of Exotic Species in Natural Communities*, L. K. Thomas, Jr., (ed.), The U.S. National Park Service and The George Wright Society, 1988.

VanGelder, Ellen, Personal communication, February and March 2000.



*Teacher Version*

# Designing a Control Strategy That Works: Questions From the Discussion

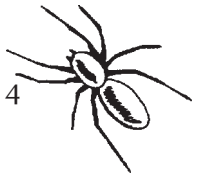
Based on the class discussion and the information provided below, answer the following questions:

- 1) Discuss the importance of each of the following characteristics of the Argentine ant to the design of a strategy to control or eradicate the ant:
  - a) Argentine ant queens are unable to fly. They mate in the nest where they were born, and if they are leaving to establish a new nest of their own, they walk a short distance away. So Argentine ant populations expand slowly outward. Most other ant species have winged queens that may fly a long distances away from their birth nests to establish a new nest of their own.

With Argentine ants, it is possible to treat the boundaries of the population to keep it from spreading further. This is because of the “budding” process through which the population expands slowly outward. A new, noncontiguous population will only be established if people transport the ants to a new place.

- b) Like most other ant species, the Argentine ant shares food through “trophallaxis.” In this process, worker ants pass regurgitated food to other workers, the brood (larvae and pupae), and the queens. Highly attractive food gets passed quickly throughout the nest.

In designing a control program aimed at eradicating ants, it is important that the workers pass on the toxicant to other ants, especially the queen, so the whole colony is poisoned and cannot repopulate itself. Since workers are the first to eat the food (then pass it on to others through trophallaxis) the toxicant needs to be slow acting so workers have a chance to pass it on before they die. Combining a slow-acting toxicant with a highly attractive bait is a key to success.



- c) The Argentine ant forms large “unicolonies” in which it is difficult to distinguish among nests. In the park, each of the two ant populations is essentially one big colony. The Argentine ants from one nest do not defend their territory against Argentine ants from another nest. In fact, worker ants move readily from nest to nest, helping out wherever they are needed.

There is no way to control the Argentine ant population one nest at a time.

- 2) In the summer of 1996, researchers conducted a study in which they measured the effect of treating segments of the ant population borders with toxic bait. One of the two study areas they chose was located on the “crater” floor, on the rapidly expanding eastern edge of the ant population. One reason the researchers cited for choosing this site was that they wanted to keep the ants away from the Hōlua campground and cabin, less than 500 meters (1640 feet) away from the boundary of the ant population.

Drawing on what you have learned about the characteristics of Argentine ants, explain why researchers would be concerned about keeping the ants away from the campground and cabin area.

The main point here is that Argentine ants disperse over long distances only through human contact. If the ants spread to the campground and cabin area, which are both heavily used by people, there is a much greater likelihood that ants will be transported to uninfested areas within or outside of the “crater.”



- 3) In August 1997, a helicopter was used to apply toxic bait to the expanding border areas of both Argentine ant populations. The entire upper population border was treated, as well as the southwest edge of the lower population border. Researchers monitored the expansion of the ant population at 84 stations along these borders.

They divided the upper study area and monitoring stations into two portions because they have different historic rates of expansion:

- The “frontcountry” or western part, where the historic rate of expansion is slower.
- The “crater” or eastern part, where the population has historically spread more rapidly.

One year after the treatment, researchers gathered the data contained in Table #1: August 1998 Ant Border Monitoring Results, August 1997-August 1998 (Student Page 5, p. 64). Use the data provided to answer the following questions, writing the formulas and each step of your calculations in the spaces below the questions. Round to the nearest one-tenth:

Mean boundary expansion = Total expansion (T)/Number of stations recording data (n)

- a) What is the mean boundary expansion for the lower population?

$$\begin{aligned} \text{MBE} &= T/n \\ \text{MBE} &= 38/37 \\ \text{MBE} &= 1.0 \text{ m/yr} \end{aligned}$$

- b) What is the mean boundary expansion for the frontcountry segment of the upper population?

$$\begin{aligned} \text{MBE} &= T/n \\ \text{MBE} &= 23/21 \\ \text{MBE} &= 1.1 \text{ m/yr} \end{aligned}$$

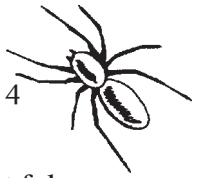
- c) What is the mean boundary expansion for the “crater” segment of the upper population?

$$\begin{aligned} \text{MBE} &= T/n \\ \text{MBE} &= 482/23 \text{ (although there are 26 stations, 3 had no data)} \\ \text{MBE} &= 21.0 \text{ m/yr} \end{aligned}$$

- d) What is the mean boundary expansion for the entire upper population?

$$\begin{aligned} \text{MBE} &= T/n \\ \text{MBE} &= 505/44 \\ \text{MBE} &= 11.5 \text{ m/yr} \end{aligned}$$





4) Fill in the table below, using the results of your calculations. Then answer the question that follows.

	Mean boundary expansion one year after treatment (m/yr)	Mean boundary expansion in previous years (m/yr)*
Lower population	<u>  1.0  </u> (n = <u>  37  </u> )	29 (1982-97 data)
Upper population	<u> 11.5 </u> (n = <u>  44 </u> )	
Frontcountry segment	<u>  1.1  </u> (n = <u>  21 </u> )	24 (1993-97 data)
“Crater” segment	<u> 21.0 </u> (n = <u>  23 </u> )	81 (1993-97 data)

### Question

Based on the data in the table above, would you say that the effort to control the spread of the Argentine ant is working or not working? Explain your reasoning.

Park researchers and resource managers believe the answer is yes, the control effort is working. Students may support their answer in many ways; perhaps the most obvious is to compare the rates of spread pre- and post-treatment. Here are some points of comparison:

- The mean rate of expansion at these stations one year after treatment was considerably lower than mean rates of expansion calculated from distribution data for previous years. [Acetate Table 1: Comparison of Pre- and Post-Treatment Boundary Expansion shows the difference. Students will have calculated some of these figures in their homework assignment.]
- The lower population expanded, on average, only one meter beyond its pretreatment range. This expansion is only about 3.5 percent of the mean expansion rate for previous years.
- Expansion on the western portion of the upper population was similar, and was only about 4.5 percent that of previous years.
- Expansion on the eastern portion of the upper population was greatest, but still only about 25 percent of the 81 meters/year calculated for the 1993-1997 time period.

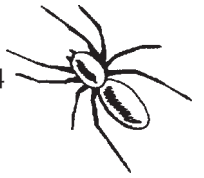
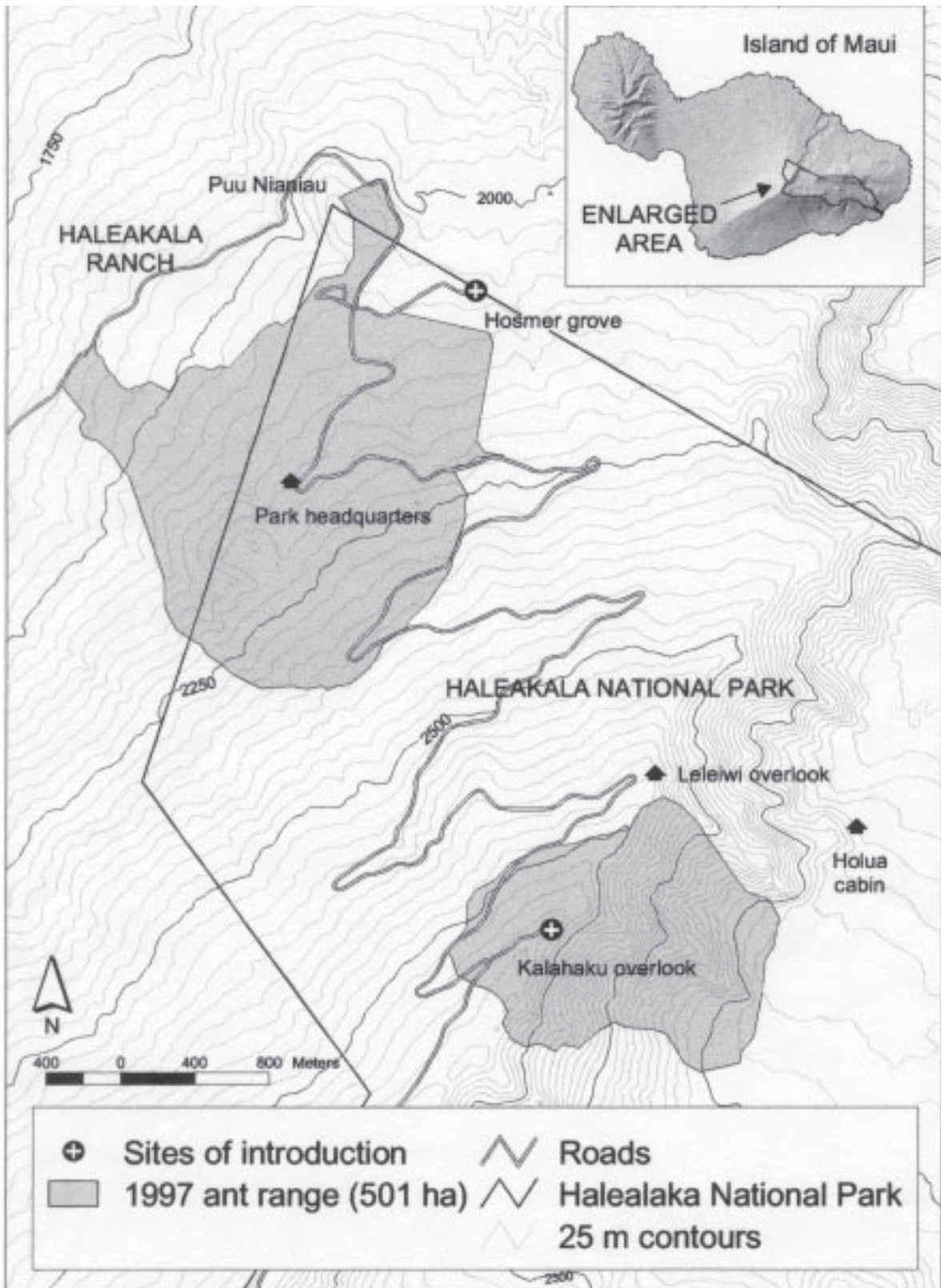


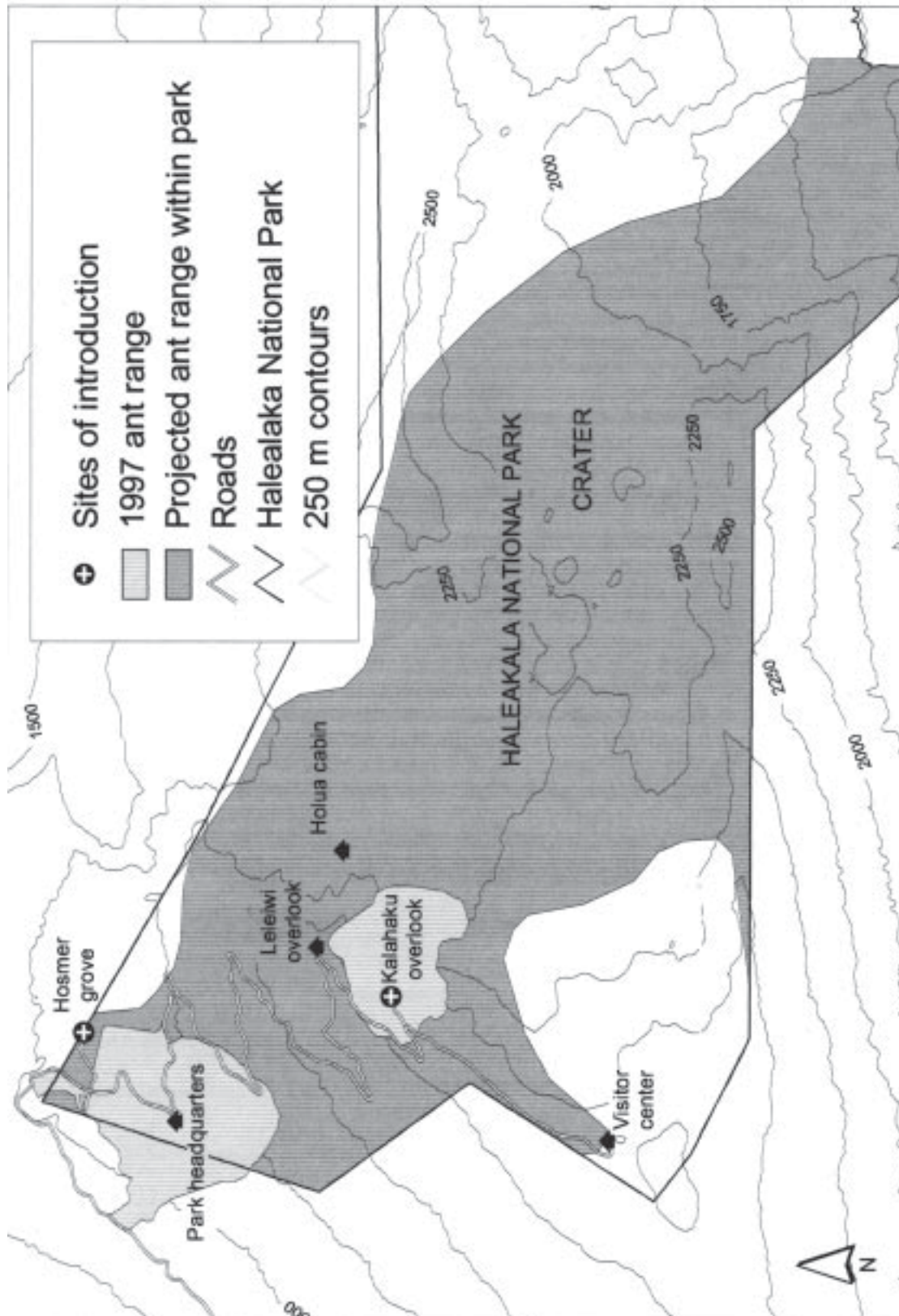
Figure 1: Argentine Ant Populations in Haleakalā National Park, 1997



Map: Krushelnycky, Paul, S. Joe, Lloyd Loope, and Arthur Medieros, unpublished data.



Figure 2: Potential Range of the Argentine Ant in Haleakalā National Park



Map: Krushelnycky, Paul, S. Joe, Lloyd Loope, and Arthur Medieros, unpublished data.

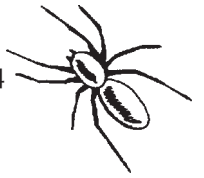
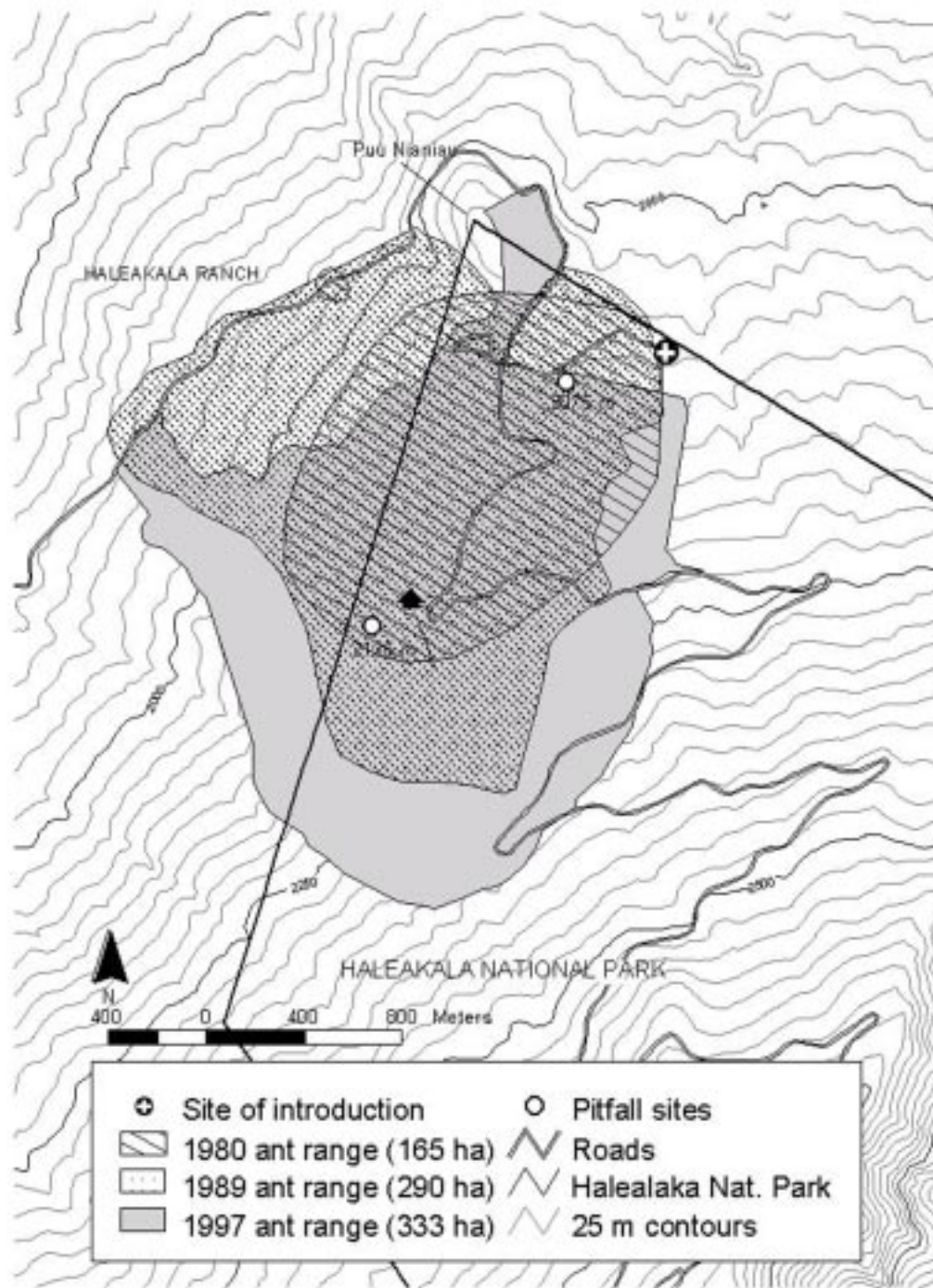


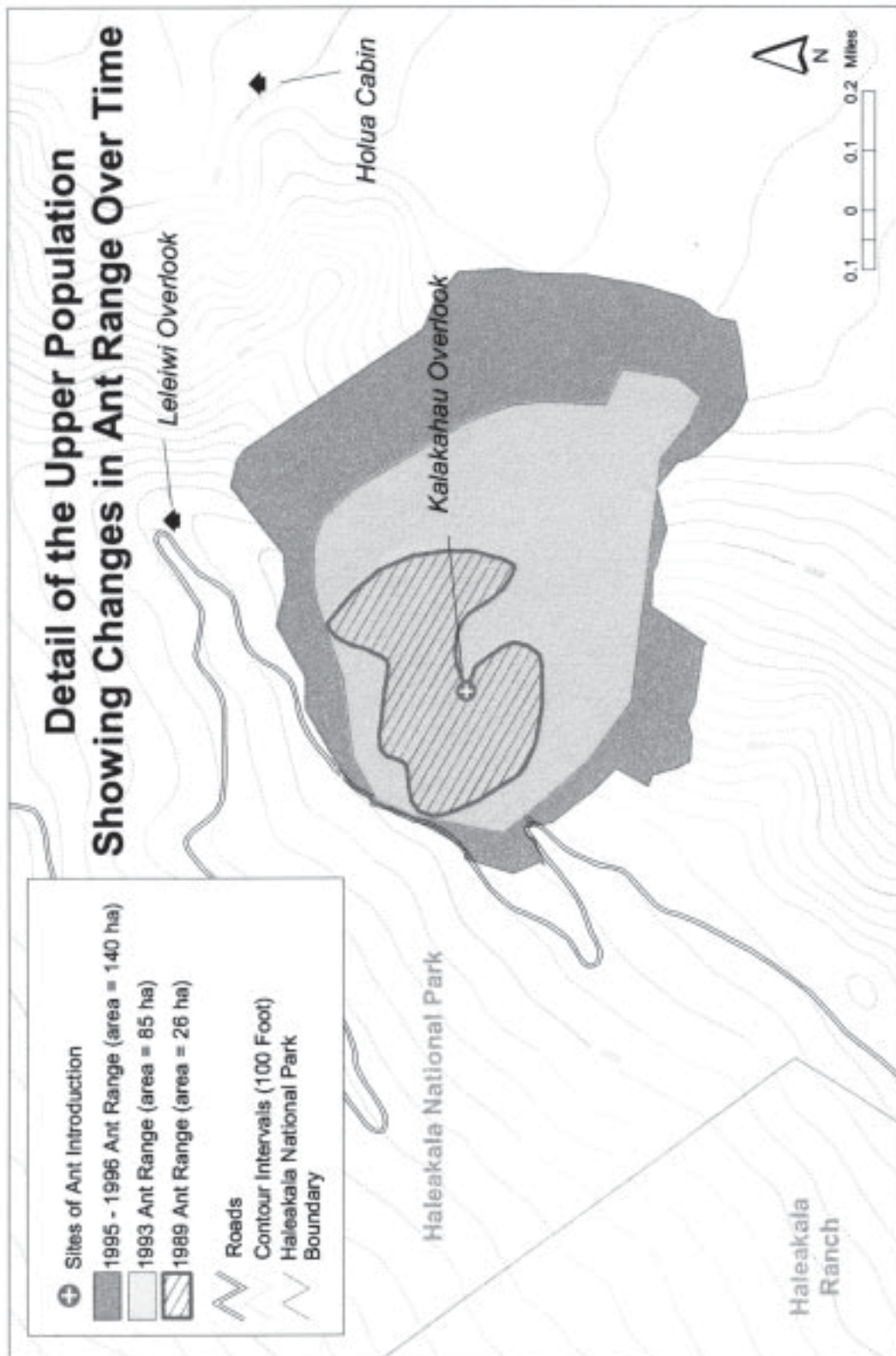
Figure 3: Spread of the Lower Population (1997 range projected)



Map: Krushelnycky, Paul, S. Joe, Lloyd Loope, and Arthur Medieros, unpublished data.



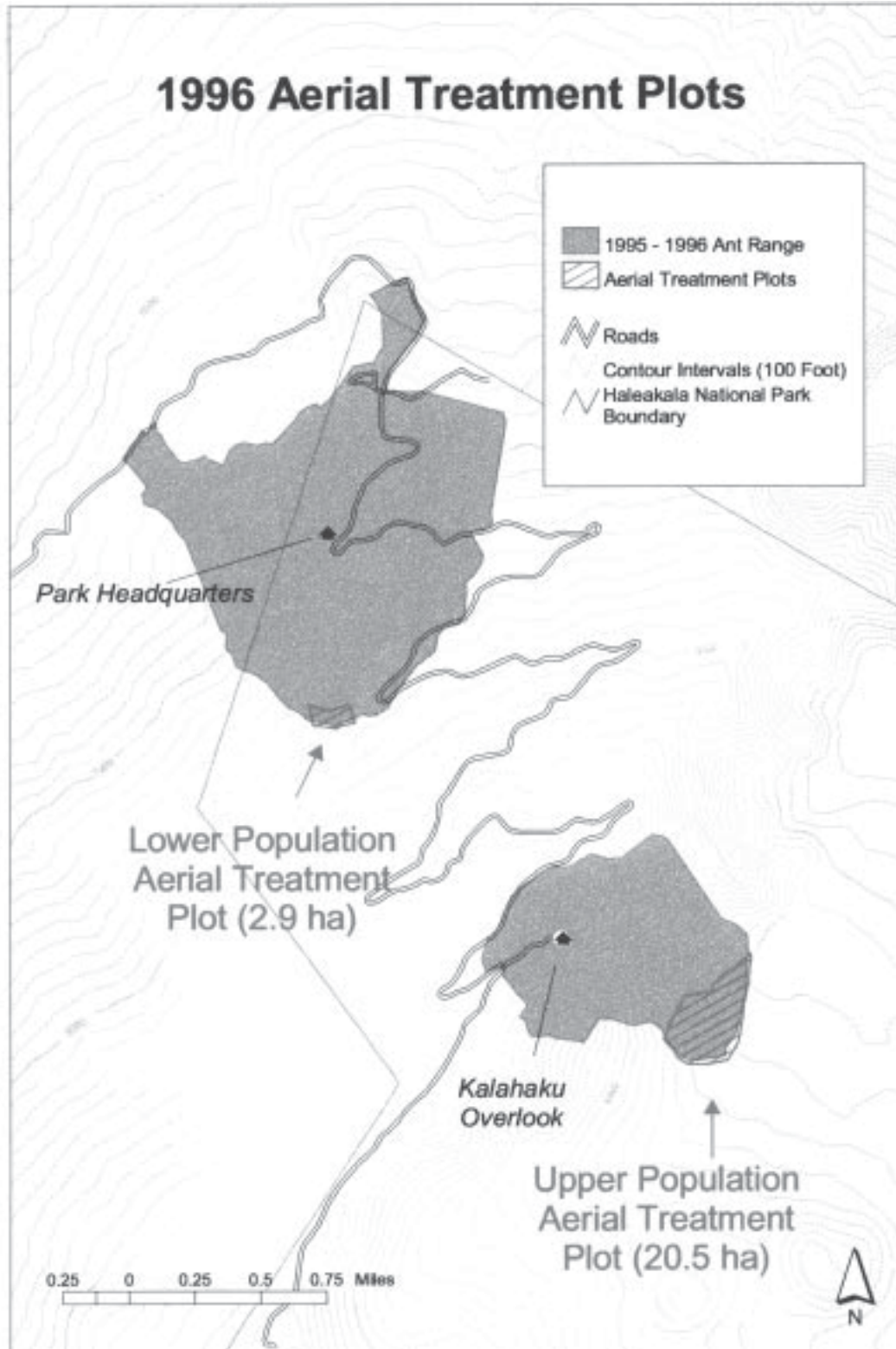
Figure 4: Spread of the Upper Population



Map: Krushelnycky, Paul, S. Joe, Lloyd Loope, and Arthur Medieros, unpublished data.



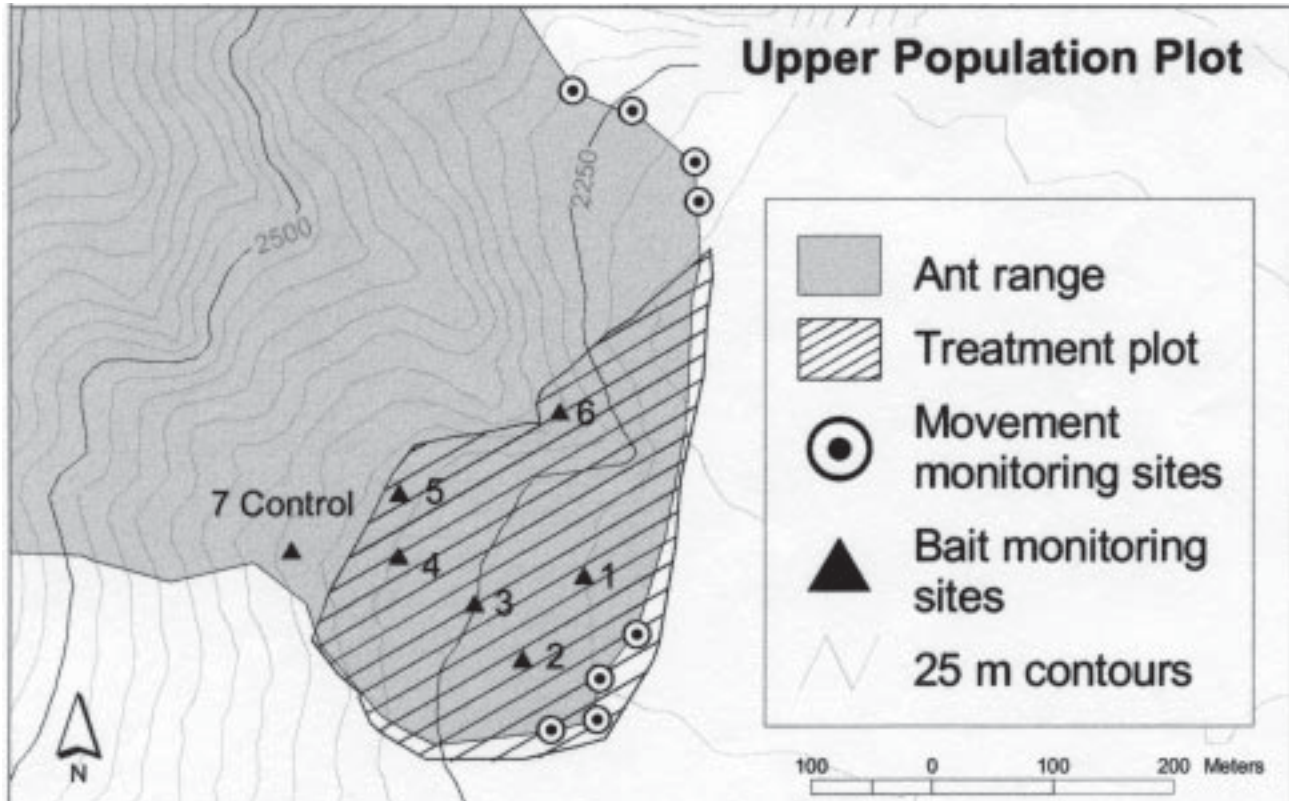
**Figure 5: 1996 Aerial Treatment Plots**



Map: Krushelnycky, Paul, S. Joe, Lloyd Loope, and Arthur Medieros, unpublished data.



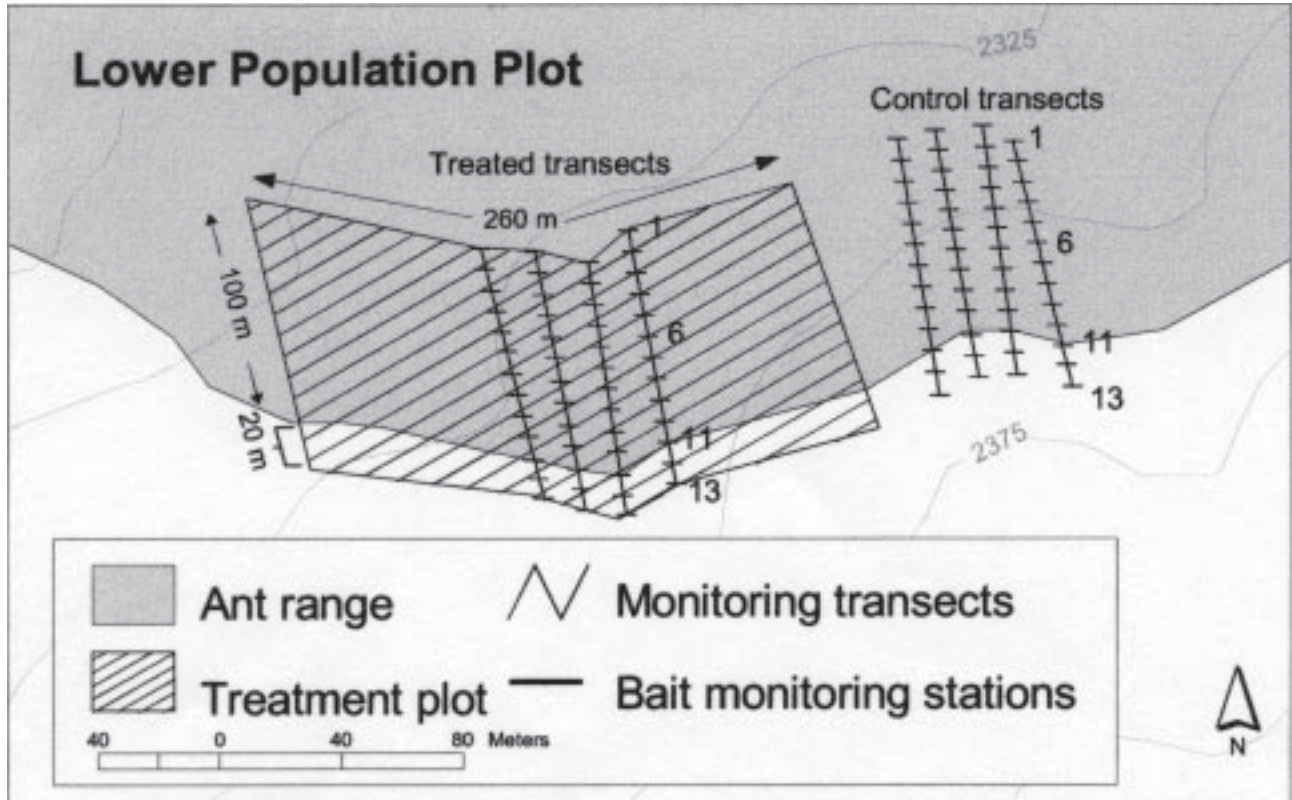
Figure 6: Upper Population Plot



Map: Krushelnycky, Paul, S. Joe, Lloyd Loope, and Arthur Medieros, unpublished data.



Figure 7: Lower Population Plot



Map: Krushelnycky, Paul, S. Joe, Lloyd Loope, and Arthur Medieros, unpublished data.



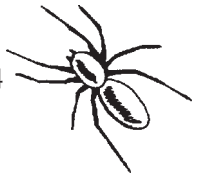
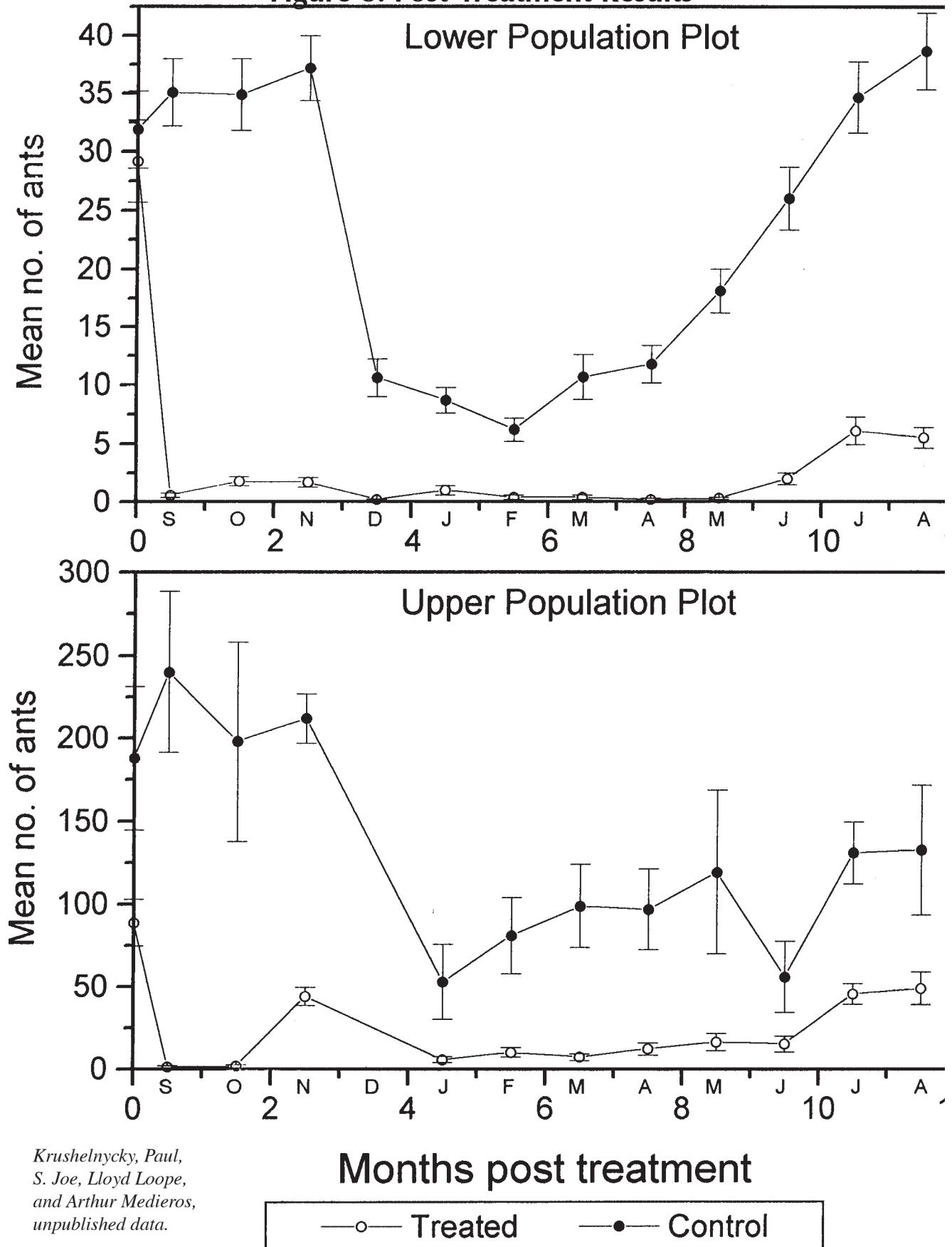


Figure 8: Post-Treatment Results



*Krushelnycky, Paul,  
S. Joe, Lloyd Loope,  
and Arthur Medieros,  
unpublished data.*

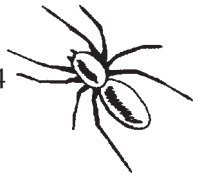
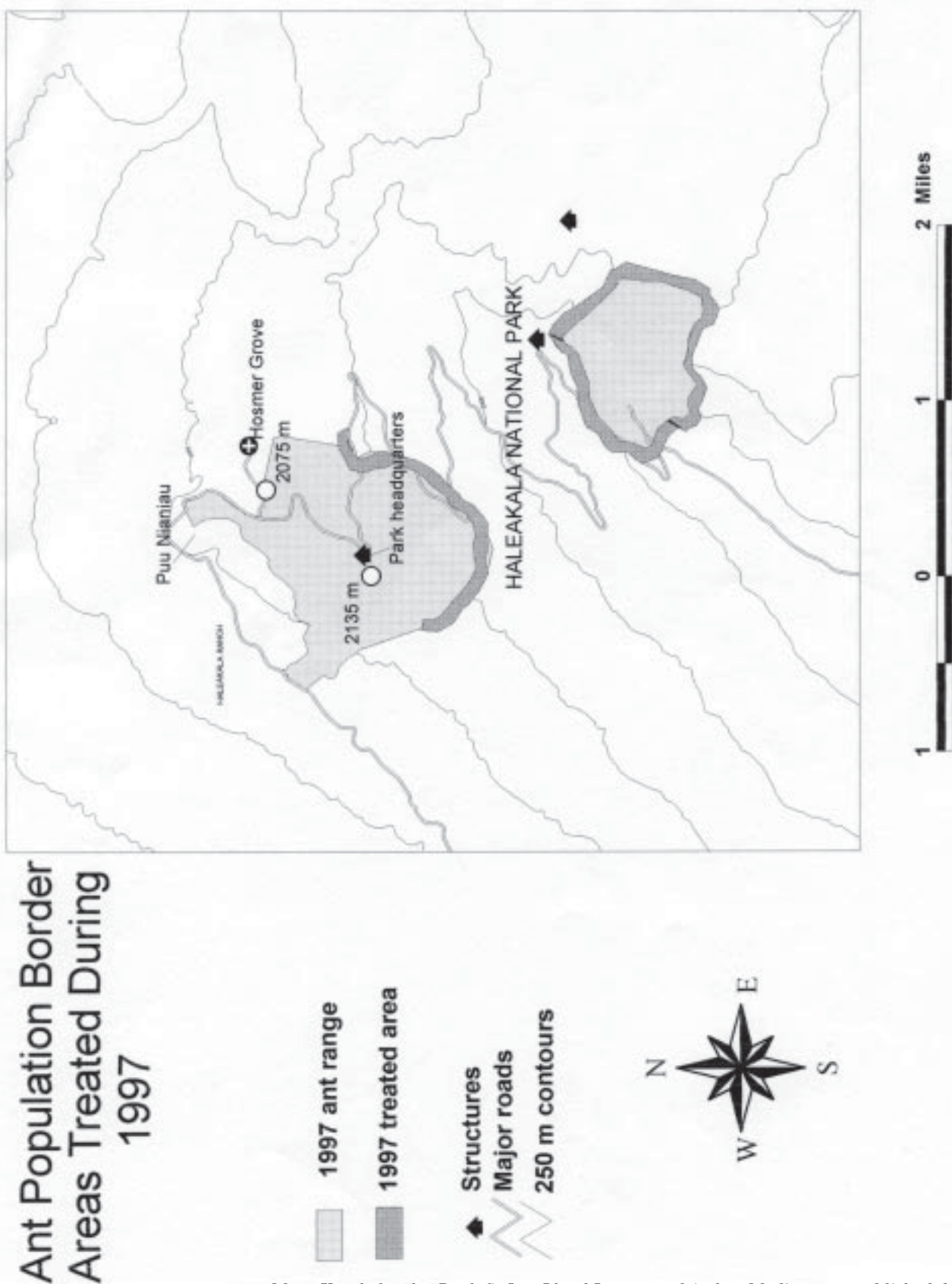


Figure 9: Population Border Areas Treated During 1997



Map: Krushelnycky, Paul, S. Joe, Lloyd Loope, and Arthur Medieros, unpublished data.



Figure 10: Lower Population Monitoring Sites



# Lower Population Monitoring Sites

- ◆ 1997 monitoring stations
- 1997 treatment areas
- ~ 1000ft contour interval
- ~ 100ft contour interval
- major roads



Map: Krushelnycky, Paul, S. Joe, Lloyd Loope, and Arthur Medieros, unpublished data.

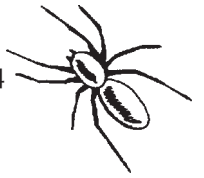


Figure 11: Upper Population Monitoring Sites



# Upper Population Monitoring Sites

- ◆ 1997 monitoring stations
- 1997 treatment areas
- ~ 1000ft contour interval
- ~ 100ft contour interval
- major roads



Map: Krushelnycky, Paul, S. Joe, Lloyd Loope, and Arthur Medieros, unpublished data.

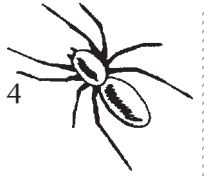


**Table 1: Comparison of Pre- and Post-Treatment Boundary Expansion**

	Mean boundary expansion one year after treatment (m/yr)	Mean boundary expansion in previous years (m/yr)
Lower population	__1.0__ (n = __37__)	29 (1982-97 data)
Upper population	__11.5__ (n = __44__)	
Frontcountry segment	__1.1__ (n = __21__)	24 (1993-97 data)
Crater segment	__21.0__ (n = __23__)	81 (1993-97 data)

*Krushelnycky, Paul, S. Joe, Lloyd Loope, and Arthur Medieros, unpublished data.*





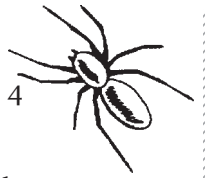
- c. The Argentine ant forms large “unicolonies” in which it is difficult to distinguish among nests. In the park, each of the two ant populations is essentially one big colony. The Argentine ants from one nest do not defend their territory against Argentine ants from another nest. In fact, worker ants move readily from nest to nest, helping out wherever they are needed.

- 2) In the summer of 1996, researchers conducted a study in which they measured the effect of treating segments of the ant population borders with toxic bait. One of the two study areas they chose was located on the “crater” floor, on the rapidly expanding eastern edge of the ant population. One reason the researchers cited for choosing this site was that they wanted to keep the ants away from the Hōlua campground and cabin, less than 500 meters (1640 feet) away from the boundary of the ant population.

Drawing on what you have learned about the characteristics of Argentine ants, explain why researchers would be concerned about keeping the ants away from the campground and cabin area.







4) Fill in the table below, using the results of your calculations. Then answer the question that follows.

	Mean boundary expansion one year after treatment (m/yr)	Mean boundary expansion in previous years (m/yr)
Lower population	_____ (n = _____)	29 (1982-97 data)
Upper population	_____ (n = _____)	
Frontcountry segment	_____ (n = _____)	24 (1993-97 data)
"Crater" segment	_____ (n = _____)	81 (1993-97 data)

**Question**

Based on the data in the table above, would you say that the effort to control the spread of the Argentine ant is working or not working? Explain your reasoning.



**Table #1: August 1998 Ant Border Monitoring Results  
August 1997-August 1998 (One Year)**

Lower Population		Upper Population Frontcountry Segment		Upper Population "Crater" Segment	
Station #	Expansion (m)	Station #	Expansion (m)	Station #	Expansion (m)
1	0	44	0	38	12
2	0	45	0	39	0
3	10	46	0	40	10
4	0	47	0	41	35
5	0	48	0	42	21
6	0	49	5	43	2
7	0	50	0		
8	0	51	0	65	0
9	0	52	0	66	0
10	0	53	0	67	0
11	0	54	0	68	15
12	0	55	18	69	0
13	0	56	0	70	0
14	0	57	0	71	0
15	0	58	0	72	0
16	0	59	0	73	8
17	0	60	0	74	0
18	0	61	0	75	18
19	0	62	0	76	31
20	0	63	0	77	no data
21	0	64	0	78	0
22	0			79	no data
23	0			80	no data
24	0			81	156
25	0			82	74
26	0			83	49
27	0			84	51
28	0				
29	0				
30	0				
31	0				
32	0				
33	12				
34	16				
35	0				
36	0				
37	0				



Alpine/Aeolian Unit 5

# Observatories, Transmitters, & Sacred Places

## Overview

Among other things that make Haleakalā special in Hawaiian tradition, this volcano is the house of the sun, a sacred place used sparingly by humans and held in reverence as a place of prayer. Haleakalā is the *piko*, the navel or spiritual center, of all of the islands that once were joined as *Maui Nui*: Maui, Moloka‘i, Lāna‘i, and Kaho‘olawe.

Today, Haleakalā attracts many other human uses, some of which come into conflict with each other. These conflicting perspectives must be resolved in order to ensure that Haleakalā will continue to be a special place for Maui residents and visitors alike.

In this unit, students learn more about the scientific research that takes place within the Haleakalā Observatories complex and what makes the summit a good place for that kind of research. Then they explore different ways that people think the summit area should be used, focusing on the unresolved issue of the location of broadcast facilities on the mountain.

## Length of Entire Unit

Five 50-minute periods

## Unit Focus Questions

- 1) What significance do different people place on the summit area of Haleakalā?
- 2) How do those perspectives influence views about how the summit area should be used?
- 3) What are students’ opinions about a real-life proposal concerning the use of the summit area?



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## Unit at a Glance

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### Activity #1

#### Exploring the Importance of the Summit

Students explore the significance of the summit area of Haleakalā from as many perspectives as they can think of, including its traditional Hawaiian importance and its suitability as a place for observatories.

#### Length

One class period

#### Prerequisite Activity

None

#### Objectives

- Describe personal responses to a Hawaiian chant about the summit area.
- Identify different perspectives about the importance of the summit area.
- Discuss characteristics that make the summit suitable for observatories.

#### DOE Grades 9-12 Science Standards and Benchmarks

**LIVING THE VALUES, ATTITUDES, AND COMMITMENTS OF THE INQUIRING MIND:** Students apply the values, attitudes, and commitments characteristic of an inquiring mind.

- Objectivity: Evaluate various perspectives and their implications before drawing conclusions.

### Activity #2

#### In-Class Public Forum

Students use existing points of view to develop testimony for an in-class “public forum” on an issue about the appropriate use of the summit area. Students also articulate their own perspectives on this issue.

#### Length

Four class periods preceded by a homework reading assignment

#### Prerequisite Activity

Activity #1 “Exploring the Importance of the Summit”

#### Objectives

- Examine and describe one perspective about the importance of the summit area.
- Formulate and express an opinion about the value of the summit area and which uses are appropriate there.

#### DOE Grades 9-12 Science Standards and Benchmarks

**LIVING THE VALUES, ATTITUDES, AND COMMITMENTS OF THE INQUIRING MIND:** Students apply the values, attitudes, and commitments characteristic of an inquiring mind.

- Objectivity: Evaluate various perspectives and their implications before drawing conclusions.

**RELATING THE NATURE OF TECHNOLOGY TO SCIENCE:** Students use the problem-solving process to address current issues involving human adaptations in the environment.

- Identify and explain current issues or problems based on evidence found in available information.
- Evaluate alternative solutions for effectiveness based on appropriate criteria.



## Bonus Activity

### What Goes On at the Observatories?

Students perform Internet research to learn about the work that is being done in the observatories on Haleakalā.

#### Length

Student research time plus one class period  
This activity may also be given as homework only.

#### Prerequisite Activity

None

#### Objective

- Use the Internet to find information about the research or other work that takes place at one of the facilities in the Haleakalā Observatories complex.

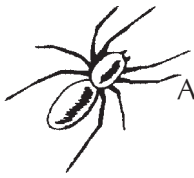
#### DOE Grades 9-12 Science Standards and Benchmarks

LIVING THE VALUES, ATTITUDES, AND COMMITMENTS OF THE INQUIRING MIND:  
Students apply the values, attitudes, and commitments characteristic of an inquiring mind.

- Use research techniques and a variety of resources to complete a report on a project of one's choice.
- Ask questions, explain, and elaborate how science is a way of thinking and knowing the world around us.

### Enrichment Ideas

- Begin the unit with an activity that gets students interested in what can be learned about the sun from earth. This is an important component of the research taking place at Haleakalā Observatories. Many activities can be found on websites in the “Resources for Reading and Research” listing below. A simple one entitled, “Reflections of a Star: How to Find the Angular Diameter of the Sun” can be found on the Exploratorium website at <[www.exploratorium.edu/snacks/suns\\_angular\\_diameter/index.html](http://www.exploratorium.edu/snacks/suns_angular_diameter/index.html)>.
- Have students write “letters to the editor” based on their own views about how the summit of Haleakalā should be used.
- Have students read chapter 25, “The House of the Sun,” in *Born in Paradise*, Armine von Tempski’s autobiography about growing up on the flanks of Haleakalā (Ox Bow Press, Woodbridge, Connecticut, 1985). This chapter describes von Tempski’s youthful adventures in the summit basin with her rancher father, Hawaiian *paniolos*, her sister, and Bishop Museum archaeologists. Several scenes from this chapter offer opportunities to compare present-day views about the summit area with views, attitudes, and uses prevalent in the past.
- During the in-class public forum, have students analyze the different viewpoints presented using the list of value systems included in the Activity #2 Student Page “Questions About the Viewpoints” (pp. 33-34).
- Give students several days to prepare for the in-class public forum by working more in-depth with the Draft Environmental Assessment (appended to this unit), interviewing



people who could shed light on the perspective they are researching, developing supporting materials or media presentations for their testimony, and so forth.

- Prior to holding the in-class public forum, have students brainstorm questions they have about the proposal to move the transmitter towers. Using the table of contents of the Draft Environmental Assessment (DEA), find out whether those questions seem to be covered in the DEA. Have students gather available information from the DEA on different topics and report to the class. You could do this prior to holding the in-class public forum.
- Have students research the Hawai‘i and federal environmental review processes. The Hawai‘i process is set forth in section 343 of the Hawai‘i code. The federal process is set forth in the National Environmental Policy Act.

## Resources for Further Reading and Research

High Altitude Observatory, a National Science Foundation laboratory, maintains educational materials related to solar research. These materials include basic sun facts, questions and answers, slides and images, suggested reading, historical material, lecture notes, and tutorials at [www.hao.ucar.edu/public/education/education.html#basic](http://www.hao.ucar.edu/public/education/education.html#basic).

Stanford Solar Center maintains on-line information and educational resources including activities based on solar research data at [solar-center.stanford.edu/](http://solar-center.stanford.edu/).

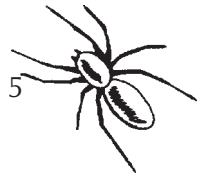
*A Guide to the Hawai‘i State Environmental Review Process* is available to download at [www.state.hi.us/health/oeqc/guidance/index.html](http://www.state.hi.us/health/oeqc/guidance/index.html).

HRS 343, the section of the Hawai‘i code that sets up the environmental review process mandating environmental assessments and environmental impact statements for specific types of proposed projects is available on-line at [www.hawaii.gov/health/oeqc/eioeq343.htm](http://www.hawaii.gov/health/oeqc/eioeq343.htm).

Office of Environmental Quality Control on-line guide to the Hawai‘i environmental review process is available at [www.state.hi.us/health/oeqc/eioeq04.htm](http://www.state.hi.us/health/oeqc/eioeq04.htm).

Scudder, Richard J., *EIS Handbook for Hawai‘i*, Office of Environmental Quality Control, Honolulu.

“The Environmental Notice,” a semi-monthly publication of the Hawai‘i Office of Environmental Quality Control, lists current environmental assessments and environmental impact statements available for public comment. Current and back issues are available to download at [www.state.hi.us/health/oeqc/notice/index.html](http://www.state.hi.us/health/oeqc/notice/index.html).



Activity #1

# Exploring the Importance of the Summit

## ● ● ● Class Period One *Exploring the Importance of the Summit*

### Materials & Setup

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- Acetate of *Nani Ke Ao i Haleakalā* chant (master, p. 9)
- Overhead projector and screen

### Instructions

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- 1) Display the chant and read it aloud, or have a student read it. Ask students to focus on the feelings the chant invokes.
- 2) After the chant has finished, ask students to write down the feelings the chant brought out, or what it made them think about. Then ask several students to share what they wrote.
- 3) Display the acetate on the overhead and read aloud the English version of the chant. Ask students to write down whether they have different thoughts and feelings now that they know what the chant means. Ask a few students to share their reactions.
- 4) Ask the class to brainstorm answers to this question: Why is the summit area of Haleakalā important to people? Encourage students to think about people in the past, present, and future. Write student responses on the board or overhead. Try to generate as complete a list as possible, making sure that something related to the research and other work done at the observatories gets on the list, as well as the location of television and radio transmitters.
- 5) Lead a lecture and discussion of the characteristics of the summit area that make it suitable for observatories. See the teacher background (pp. 6-8) for details.

### Journal Ideas

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- Think of a situation in which you felt very differently about something than another person did. Were you able to work out your differences? If so, how? If not, why not?
- Write a poem, short story, or Hawaiian *mele*, or draw pictures that illustrate what Haleakalā means to you.
- Think about all the reasons that the summit of Haleakalā is important to people. Which do you think are the most important?
- If a company or government agency wanted to build a new observatory at the summit, do you think they should be allowed to do so? Why or why not?

### Assessment Tools

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- Participation in class discussion
- In-class writing
- Journal entries



### Teacher Background

## What Makes the Summit Area of Haleakalā Suited to Observatories?

Near the summit of Haleakalā, which rises 3056 meters (10,023 feet) from sea level, the Haleakalā Observatories occupy a site that is considered to be among the top five percent in the world for locating ground-based astronomy research and monitoring facilities.

Since 1961, several facilities have been built on this site to study and track a variety of things having to do with the sun and moon, the earth's atmosphere, satellites, and other objects traveling through space. These facilities include:

### The Air Force Maui Space Surveillance Complex (MSSC)

Space surveillance activities are conducted here for the U.S. Department of Defense. Find more information at <ulua.mhpc.af.mil/>.

### Cosmic Ray Neutron Monitor Station

A neutron monitor detects incoming energy from cosmic rays emanating from sources including solar flares. Find more information at <ulysses.sr.unh.edu/NeutronMonitor/neutron\_mon.html>.

### Lunar and Satellite Ranging (LURE) Observatory

Laser equipment is used to track satellites. Until 1990, this equipment was also used to track the distance between the earth and the moon, helping scientists measure phenomena such as tectonic plate shifts. Find more information at <koa.ifa.hawaii.edu.>.

### Mees Solar Observatory

The main instrument used here is the imaging vector magnetograph, which enables researchers

to measure the electric currents passing through selected regions of the sun's surface. Research topics include solar flares, magnetic fields on the sun, and solar oscillations. Find more information at <koa.ifa.hawaii.edu> and <www.ifa.hawaii.edu/research>.

For a listing of related websites, see Bonus Activity "What Goes On at the Observatories?" Student Page "Surf the Net to Research the Haleakalā Observatories" (pp. 36-38).

### Summit Advantages

Why is the Haleakalā High Altitude Observatory Site such a good place for these types of research and other work?

- Astronomers prefer to work on high mountain tops in order to have the clearest view possible of objects in space. In general, high mountain tops are above most of the dust, clouds, and water vapor found in the lower atmosphere.
- The summit area of Haleakalā is above the trade wind inversion much of the time. (See Alpine/Aeolian Unit 2 "Mauna Lei Mystery" for background information about the tradewind inversion.) Because of this, there is a good proportion of days suitable for viewing. The trade wind inversion restricts the influx of air pollution, clouds, and water vapor from lower elevations.
- At night, a usual downslope flow of air enhances clarity by keeping moisture and particulates from reaching the summit or accumulating there.
- Because Haleakalā is in the middle of the ocean, the air is even cleaner and clearer than





it is at many landlocked sites. In addition, the fact that air currents travel over the ocean, rather than large land masses, before they reach Haleakalā means that there is less air turbulence. Air turbulence is caused by differences in air density caused by differential heating. Air flows traveling across land masses can pick up heat, causing turbulence when they mix with the cooler air at higher elevations. This causes blurriness in the image, reducing the quality of what astronomers call “seeing,” or visibility through the atmosphere. The air flows coming directly from the ocean rather than over land are called “free atmosphere.” They generally contain less turbulence and make for clearer viewing.

At Haleakalā, the wind usually blows across the summit basin, coming from the northeast.

As it traverses the landscape, the air heats up. It also rises off the lip of the summit basin wall and forms a turbulent eddy, despite the fact that the density differences are minor. Because of this, the quality of “seeing” at Haleakalā is not as good as it is at Mauna Kea. But it is still better than most other observatory locations around the world. (When the winds are light and steady from the southeast, scientists at the Mees Solar Observatory report the best viewing conditions. The winds then are not traversing so much land before reaching the observatory.)

- Because Haleakalā is in the tropics, scientists can view some of the southern sky from there. Observatories on the continental United States are too far north for this.

## Adaptive Optics: Advancing Technologies for Even Better “Seeing”

The seeing is already quite good at Haleakalā Observatories, but technological advances are making it even better. “Adaptive optics” are being used in the Advanced Electro-Optics System (AEOS) telescope, which is part of the Maui Space Surveillance Complex.

“Adaptive optics” (or AO) refers to optical equipment that compensates for the effect of turbulence in the lower atmosphere as well as high above the earth’s surface. Small temperature variations in the atmosphere cause the light entering different parts of a telescope pupil to travel at slightly different speeds. That’s what causes blurriness. The AO system used in the AEOS telescope senses these differences and corrects for them using a flexible mirror. (Modern telescopes use mirrors rather than lenses.) Since the atmosphere is constantly moving, the AO system adjusts rapidly, more than 100 times per second!

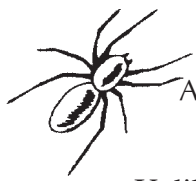
The following websites are starting points if you or your students would like to learn more about adaptive optics:

Adaptive Optics at the University of Hawai‘i at <[www.ifa.hawaii.edu/ao/](http://www.ifa.hawaii.edu/ao/)>. Includes downloadable movies of the Hōkūpa‘a (“immovable star”) telescope correcting for turbulence.

Herzberg Institute of Astrophysics page on adaptive optics and air turbulence at <[www.hia.nrc.ca/moffatt/eng/adaptive/adaptive.html](http://www.hia.nrc.ca/moffatt/eng/adaptive/adaptive.html)>.

International Society for Optical Engineering overview of adaptive optics at <[www.spie.org/web/oer/february/feb98/adapt.html](http://www.spie.org/web/oer/february/feb98/adapt.html)>.

Lawrence Livermore National Laboratory page on adaptive optics at <[www.llnl.gov/str](http://www.llnl.gov/str)>.



- Unlike the weather on high mountains in many other parts of the world, the weather on Haleakalā is only infrequently severe enough to hamper the use of observatory facilities. The weather is more reasonable on Haleakalā than it is even on nearby, but higher, Mauna Kea.
- Temperatures are moderate for the altitude.
- There is more oxygen per volume of air available on Haleakalā than on higher elevation mountains such as Mauna Kea. This makes it easier for researchers and maintenance personnel to work there.
- There is minimal light pollution from nearby urbanized areas.
- Access to the summit is relatively easy. The road is paved all the way to the top, and is seldom closed by bad conditions or weather.

### One Significant Disadvantage

Discussing the advantages of Mauna Kea as an observatory site, Saul Price noted that “radio telescopes experience an almost complete absence of electrical interference from urban or other sources.” On Mauna Kea, radio and television broadcasting transmitters are not allowed in the Mauna Kea Science Reserve. But on Haleakalā, the observatories are in close proximity to several powerful broadcast facilities, some of which are immediately adjacent to the observatories.

The radio frequency interference (RFI) caused by the proximity of the broadcast facilities to the observatories has a different effect depending upon the device receiving the interfering signals. Some types of equipment are particularly sensitive to the radio frequency signals, which interfere with their ability to amplify, process, and display weak electrical signals associated with

astronomical measurements. In some cases, RFI has been so bad that screens that normally display data instead display fuzzy television pictures.

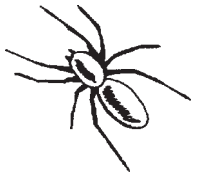
This is one example of a conflict between different uses of the summit area.

### Sources

KC Environmental, Inc., *Draft Environmental Assessment and Anticipated Finding of No Significant Impact (FONSI) for a Coordinated Broadcast Facility at Haleakala, Maui, Hawaii*, University of Hawai‘i Institute for Astronomy, Honolulu, 1998.

Price, Saul, “Hawai‘i as a Site for Research in Astronomy and Climate Change,” in *Prevailing Trade Winds: Weather and Climate in Hawai‘i*, Marie Sanderson (ed.), University of Hawai‘i Press, Honolulu, 1993.

Mickey, Donald. Personal interview, January 2000.



## Nani ke Ao i Haleakalā

*Nani ke Ao i Haleakalā  
'Ohu'ohu i ka noe o uka  
'A 'ahu i ke kapa o ka hau  
Anu e kai o Kahului  
E hului pau mai kaula  
I ua mea nei he aloha  
E ko a pa'a ka mana'o  
I lua no ku'u makemeke*

Adorned with the mists of the upland  
Dressed in a garment of snow  
Whose cold reaches down to Kahului  
Let us take all to ourselves  
This thing that is called love  
Grip and hold fast to the thought  
That accompanies my desires





Activity #2

# In-Class Public Forum

## ● ● ● In Advance *Student Reading*

- Assign Student Page “A Proposal to Relocate Broadcast Facilities on Haleakalā” (pp.13-17) as homework reading.

## ● ● ● Class Period One *Exploring the Relocation Proposal*

### Materials & Setup \_\_\_\_\_

*For each student*

- Student Page “Different Points of View” (pp. 18-30)
- Student Page “Different Views in the News” (pp. 31-32)
- Student Page “Questions about the Viewpoints” (pp. 33-34)

### Instructions \_\_\_\_\_

- 1) With the whole class, brainstorm answers to these questions: Who would care about this proposal to move the radio and television transmitter towers? Why would they be concerned?
- 2) Review key elements of the proposal with the class, using the information provided in the student background sheet.
- 3) Before you wrap up for the day, have students count off by sevens, writing down their number as they say it. Make reading and homework assignments based on students’ numbers:
  - a) Students should read the numbered viewpoint in the Student Page “Different Points of View” that corresponds to their number (one to seven).
  - b) All students should also read the Student Page “Different Views in the News.”
  - c) All students answer the questions on the Student Page “Questions about the Viewpoints.”

## ● ● ● Class Periods Two and Three *Preparing Testimony*

### Materials & Setup \_\_\_\_\_

*For each group of three to four students*

- One photocopy of the “Summary and Anticipated Determination” section from the Draft Environmental Assessment (DEA) for the development of a coordinated broadcast facility on Haleakalā. (The DEA is included as an appendix to this unit.)

### Instructions \_\_\_\_\_

- 1) Divide the students into small groups based on the views they read. There should be one group representing each viewpoint. Each group is to prepare for a “public hearing” on whether the transmitters should be moved to the proposed site at Kalepeamoā. You will hold this public meeting in class in two days.



During these class periods, each group will create a four to six minute testimony for that public hearing, as convincing as possible, based on the viewpoint they read. They may use visuals or other support for their presentation if they want to. They may come up with research tasks and divide these among group members as homework.

- 2) Each group should have a copy of the “Summary and Anticipated Determination” section of the Draft Environmental Assessment. This provides additional background about the project and the findings of the DEA. The table of contents for this section will help students find their way quickly to important information.
- 3) As an additional resource, you may wish to photocopy other parts of the draft environmental assessment for students, especially Chapter Four “The Affected Environment,” and Chapter Five “Environmental Effects and Potential Mitigations.”

### ● ● ● Class Period Four *In-Class Public Forum*

#### Instructions

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- 1) Hold the “public forum” by having each team give its “testimony” to the entire class, allowing a few minutes for questions before moving on to the next one. If there is time left over at the end of class, hold a general discussion about what the most convincing presentations were and why, which perspectives students agree with, and what they think should be done about moving the transmitters. You may want to continue this summary discussion during the next class period.

#### Journal Ideas

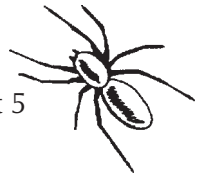
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- Do you agree or disagree with the perspective you were assigned in the public hearing? How did it feel to argue for that point of view?
- What is *your* perspective on whether the coordinated broadcast facility should be built at Kalepeamoā?
- What would you need to learn more about in order to make an informed decision about siting broadcast facilities at Kalepeamoā?
- Read the descriptions of value systems in the Student Page “Questions About the Viewpoints,” and explain which value systems show up most strongly in your personal point of view.

#### Assessment Tools

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- Participation in class discussions
- Student Page “Questions About the Viewpoints”
- Participation with group in putting together testimony
- Testimony given in class: Evaluate on the basis of thoroughness, reasoning, and presentation.
- Journal entries



# A Proposal to Relocate Broadcast Facilities on Haleakalā

High up near the summit of Haleakalā, a conflict has been brewing for years. At the center of this conflict are researchers who use sensitive electronic equipment in their work at Haleakalā Observatories,

and broadcasters, whose radio and television communication facilities produce high-powered signals. The signals from the broadcast facilities can interfere with the electronic equipment at

the observatories. Imagine sitting down at a computer screen expecting to review data from your most recent solar observations and instead seeing a blurry image of the local weather report!

The “observatories” (buildings equipped for observing natural phenomena, as in astronomy) and broadcast facilities have grown up side-by-side near the summit. The summit offers atmospheric and space researchers an accessible high-elevation vantage point for their research. The summit provides radio and television broadcasters coverage of Maui, the windward side of O‘ahu, and the Kona coast of Hawai‘i.

From the summit of Haleakalā, there are also clear microwave paths to receive transmissions from studios on O‘ahu that can in turn be transmitted to other areas.

There are not too many options for resolving this situation. Commercial broadcasters now occupy six sites on Haleakalā, most of which are next to or even within the 18-acre Haleakalā High

Altitude Observatory site. New technological developments mean that researchers at the observatories are using electronic equipment that is increasingly sensitive to radio frequency interference (RFI) from the transmitters. There have been some efforts to shield the research equipment, but shielding is expensive and only partially effective.

The situation is bound to get worse, not better, if the broadcast facilities are left where they are. Applications

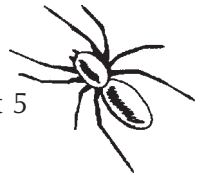


*LURE observatory  
(Photo: Michael Maberry)*



*Transmitter facilities in the saddle area  
(Photo: Michael Maberry)*

for construction permits for several new stations have been submitted, and some have been approved. In addition, the federal government has



*Air Force AEOS telescope  
(Photo: U.S. Air Force)*

mandated a transition to digital television. During this transition period, broadcasters will be constructing new digital transmitters to accompany the existing analog facilities. After a number of years, the analog transmitters will be phased out. In the meantime, however, there will be more transmitters and more RFI for the observatories.

### A Proposed Solution

In 1998, the University of Hawai‘i Institute for Astronomy formally proposed moving all of the broadcast facilities in the summit area to a single site about a mile away from Haleakalā Observatories. Its aim was to reduce the proliferation of transmitter facilities at the summit and to protect the observatories from radio frequency interference. The Institute commissioned a site selection study and prepared an “environmental

assessment” (this term is defined in the sidebar on the environmental review process).

Four alternative sites were examined to see:

- 1) Whether they would reduce RFI to an acceptable level at the observatories, and
- 2) If they would provide adequate coverage for broadcast facilities.

Based on that analysis, a site along the southwest rift zone near Kalepeamo Pu‘u was chosen as the best option. Therefore, the likely impacts of developing a coordinated broadcast facility at the Kalepeamo site were studied. The results of that analysis were published in the Draft Environmental Assessment.

### The Kalepeamo Site Plan

The proposed facility would be built on land owned by the state of Hawai‘i and managed as conservation land. It would be at an elevation of 2900 meters (9250 feet) on the southwest rift zone of Haleakalā. Access to the site is along Skyline Drive, an unimproved, gated road that is sometimes used as a trail by hikers, hunters, and mountain bikers.

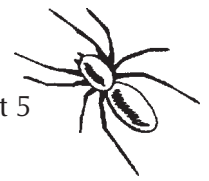


*Antennae with Pu‘u‘ula‘ula (Red Hill) in the background (Photo: Michael Maberry)*

A utility corridor already exists along Skyline Drive, making it easy to extend electricity and telephone service to the site. A diesel generator would provide backup

power, requiring an above-ground fuel storage tank. Non-potable water would be collected from a roof catchment system. Maintenance workers at the facilities would carry in their own drinking water. A septic system would be installed for sewage disposal.





The proposed coordinated broadcast facility would include as many as four antenna towers, each of which would be no taller than 61 meters (199 feet). Transmitters and other equipment would be housed in individual shelters or in a single building with separate rooms. Other rooms (or separate buildings) would house the power distribution center, the standby generator, and toilet facilities.

The broadcast facility would be operated by remote control from Honolulu. Normally, the only people coming to the facility would be performing routine maintenance two to four times a month for each station. Fuel tanks for the generator would need to be topped off between one and four times per year.

## Potential Impacts Considered In the Environmental Assessment

The environmental assessment explored a number of possible impacts of the construction and operation of the proposed facility. They included:

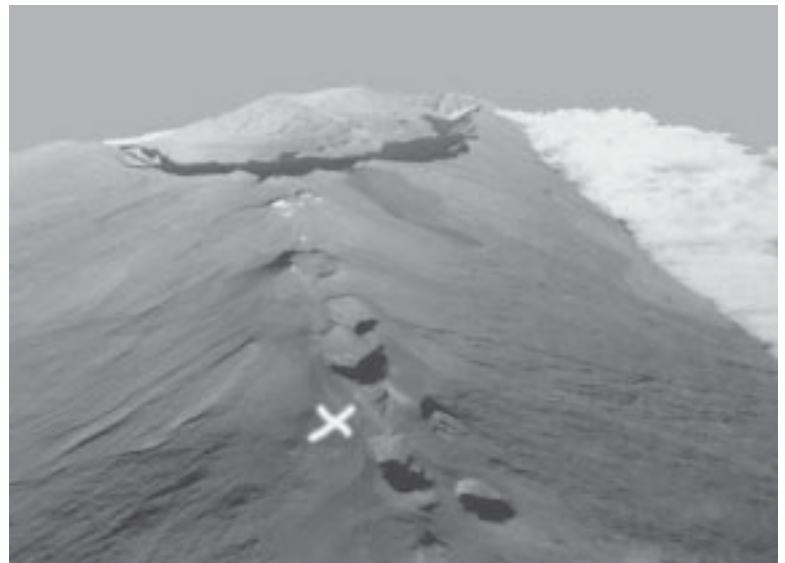
### Air Quality, Traffic, Noise

Construction activities would generate dust, especially along the unpaved access road, and intermittent high noise levels. During construction, a small increase in traffic on the road to the summit would be expected. A small number of large, oversize loads would be timed during off-peak traffic hours in the park.

Once the facility became operational, there would be an estimated five to ten vehicle trips per week for maintenance and deliveries. This would cause no increase in traffic on the main Haleakalā road, since most of the tenants in the new facility would be broadcasters that already have facilities in the summit area.

## Vegetation

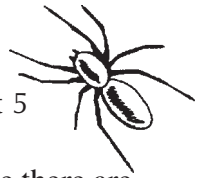
The site is sparsely vegetated with no threatened, endangered, rare, or vulnerable plants found there or in the surrounding areas. The biggest concern is the unwitting introduction of nonnative plants on construction equipment or supplies. To address this concern, the project plan proposed all incoming equipment, supplies, and construction materials be inspected by a park biologist.



*The proposed site is marked on this photo. Observatories and existing transmitter sites are uphill from this site, along the rift zone. (Photo: Frank Rozzo)*

## Birds

The endangered 'ua'u or Hawaiian dark-rumped petrel fly over the proposed site during breeding season, especially at night. 'Ua'u are prone to colliding with objects such as power lines, utility poles, and barbed wire fences. To minimize impacts on the 'ua'u, the fencing around the facility would be designed based on advice from the U.S. Fish and Wildlife Service. In addition, utility cables would be buried wherever possible. During construction, work would be done during the daytime to avoid disturbing the birds with



lights at night. Nearby ‘ua‘u nests would be monitored to assure that vibrations from the construction do not disturb the birds or their burrows.

## Invertebrates

A cursory site survey turned up no insect species unique to the area. Construction would disturb and destroy some insect habitat, but the larger concern is the potential to introduce non-native insects on equipment, supplies, and construction materials. Proposed inspections by a qualified biologist would guard against introducing alien species.

## Archaeological Sites

Five sites had been recorded in a 1995 survey of the area. The State Historic Preservation Division found that neither of the two sites directly affected by project construction were prehistoric or otherwise especially significant. Also, the proposed project would not impede worship or access to previously accessible sites for Native Hawaiians. There could be temporary closures during construction.

## Visibility

Construction equipment would be visible only in the immediate vicinity of the project. The broadcast facility itself would stand out among the rugged and barren cinder cones and craters. Few people would see the project up close, and those that do are likely to have many different opinions about it. The antennae would be visible from much of Upcountry Maui but not from most of the main visitor areas in the park.

## Infrastructure, Utilities, & Services

Maui Electric Company would extend existing power lines to the site. Power use would not affect other electric company customers. A catchment system would provide the small amount of water used at the facility. The septic system for treating waste water would have no

adverse effect on ground water because there are no springs nearby and the ground water is thousands of feet below the surface. All other waste would be taken off-site for disposal.

## Radio Frequency Interference

The facility and the observatories would be one mile apart, with shielding provided by the hilly terrain. This should make it easy for broadcasters to adjust the shape of their antenna beam to minimize RFI at Haleakalā Observatories.

## Human Health and Safety

Analyses of the risk of human exposure to radio frequency radiation found levels to be well below the maximum limits.

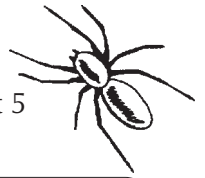
## What Happened to the Proposal

After the environmental assessment was written, the University of Hawai‘i released it for public comment. Based on their analysis, University staff and consultants believed that a “finding of no significant impact” (FONSI) was appropriate.

However, the overwhelming majority of public comments expressed concern about the potential effects of the project. In the end, the University received so many negative public comments that it could not issue a FONSI.

In Hawai‘i, the environmental review process allows two options in cases such as this one. The first option is to prepare a more detailed analysis of the project and submit this “environmental impact statement” for additional public comment. The other option is to drop the project.

The University of Hawai‘i decided not to prepare an environmental impact statement because it did not have enough money in its budget to cover the more detailed analysis required. What that means for the observatory researchers and the broadcasters is not clear. The issue of radio frequency interference has not been resolved and promises to come up again in the future.



## The Hawai'i Environmental Review Process at a Glance

Has anyone ever said to you, “Think before you act”? Have you ever found yourself wishing someone else would think before they do something that seems stupid? Getting government decision makers to think before approving a project that might harm the environment is one of the main reasons behind the Hawai'i “environmental review” process (a formal process that examines potential project affects on the environment). Many projects proposed by Hawai'i state government agencies must go through this process. There are similar review processes set up under the National Environmental Policy Act, and some counties even have similar ordinances.

Federal, state, county, and private projects can all be required to go through an environmental review process. Among other types of projects, any proposed use of state land designated as a conservation district must go through this review. The proposed site of the coordinated broadcast facility is in a state conservation district. So the environmental review was required. Here's how it works:

### Step #1: **Environmental Assessment (EA)**

A written evaluation to determine whether an action may have a significant effect

### Step #2: **Public Comment** on the EA

### Step #3: **Finding of No Significant Impact (FONSI)**

If the project will not significantly harm the environment, a FONSI is issued. There is a period of time during which people or organizations may challenge this finding in court.

**Step #4: Environmental Impact Statement (EIS)** If the project *may* have significant environmental impact or if the FONSI is struck down in court, an EIS is written to examine a proposed project's:

- environmental effects,
- effects on the community and state social and economic welfare,
- effects on economic activities,
- attempts to minimize adverse effects, and
- alternatives and their environmental effects.

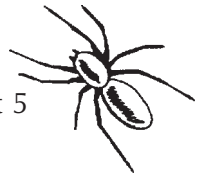
### Step #5: **Public Comment** on a Draft Environmental Impact Statement

### Step #6: **Final EIS**

The final statement includes public comments and the agency's response to them.

### Step #7: **Governor's Approval**

The final EIS is evaluated for acceptability by the governor. If accepted, the project may go forward.



# Different Points of View

The proposal to move the radio transmitters to another location on Haleakalā, away from the Haleakalā Observatories, sparked much controversy on Maui. People have many different points of view about whether the transmitters should be moved and if so, where the best location for them would be. Here are seven different viewpoints. READ THE ONE THAT CORRESPONDS TO THE NUMBER YOU WERE GIVEN IN CLASS. You may read the other viewpoints as well, but be sure to read your assigned viewpoint carefully.

## *Viewpoint #1*

### **Mike Maberry, Assistant Director Institute for Astronomy, Haleakalā Observatories**

*(These comments on the Draft Environmental Assessment were submitted on behalf of the Institute for Astronomy at the University of Hawai‘i.)*

On behalf of the University of Hawai‘i Institute for Astronomy (IfA), I would like to address our interest in the development of a coordinated broadcast facility for Haleakalā.

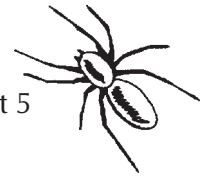
It has been incorrectly stated that commercial broadcasting preceded astronomy on Haleakalā and that our astronomers and space scientists should have avoided building telescopes near transmitters. The truth is that professional astronomical research came first. In the spring of 1951, Dr. Grote Reber, the father of radio astronomy, chose Haleakalā as one of the best sites in the world to undertake his experiments. Unfortunately, since radio astronomy cannot tolerate any level of “Radio Frequency Interference” (RFI), he soon had to abandon the site when commercial broadcasters began transmitting from the summit. In the ensuing four decades, the level of RFI has increased considerably.

What is Radio Frequency Interference? Have you ever tried to watch television when someone has turned on a vacuum cleaner in the same room? Did you notice what happened to the picture quality? You probably saw distortion, perhaps bands of light and dark or a fuzzy image, caused by competing electrical signals. If so, then you may have also noticed that when the vacuum was moved to the far side of the room the inter-

ference diminished and the picture improved. What you witnessed was a form of RFI. Moving the source (vacuum motor) away from the television reduced the interference. The same would be true for Haleakalā. Moving the source of RFI (the broadcast antennas) away from the sensitive astronomical and space surveillance equipment would have a similar beneficial effect.

The commercial broadcasters have transmitters, buildings and antennae at some six different sites on Haleakalā. Most of these sites are leased from the Department of Land and Natural Resources on month-to-month revocable permits. The University of Hawai‘i owns the 18-acre scientific reserve officially known as the Haleakalā High Altitude Observatory site, or HO. The commercial broadcasters on Haleakalā are currently located right next to and even within HO.

Beginning in the 1970s the RFI generated by the commercial broadcasters on Haleakalā began to seriously impact IfA’s ability to utilize the latest developments in sensor technology. After enduring growing frustration from the effects of RFI, we commissioned a study in 1989 to see exactly what levels of interference exist within HO. According to the International Astronomical Union, an acceptable level of RFI, measured



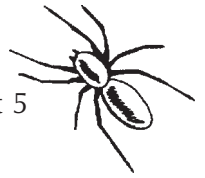
outside an observatory doing optical or infrared observations, is two microwatts per square meter. We have measured in excess of 184,000 microwatts per square meter.

At 10,000 ft., Haleakalā is obviously an excellent site from which to relay broadcast signals to windward O‘ahu, Moloka‘i, Maui and parts of the Big Island. The Federal Communications Commission (FCC) has received requests for licenses for more than 70 additional transmitters and antennas to be located on Haleakalā. Some of these are essential so that the existing broadcasters can meet the FCC’s mandate for simultaneous digital and analog transmission by the year 2004. If the state granted the requested permits without regard to where the transmitters are placed on the summit, the addition of so many more antennas would constitute both a visual blight and an additional RFI nightmare for IfA. It is therefore only logical for the State and County of Maui to work toward development of a coordinated broadcast facility on Haleakalā.

Technology has progressed such that in a coordinated facility, all commercial broadcasters and their individual antennas currently accommodated at the summit of Haleakalā can be located on two towers. Two additional antenna towers were recommended in the recent Environmental Assessment to allow for future growth well into the next century.

The IfA is preparing a Research Development Plan (RDP) that will identify what types of research can be undertaken at HO. Once the RDP is complete we can develop a Master Plan for our 18 acres (not the whole summit, as some mistakenly believe). However, we can not complete the RDP until we know how much RFI we will have to contend with.

The IfA has been working hard to resolve the problems associated with the cohabitation of astronomy and commercial broadcasters for many years and we support the concept of a coordinated, consolidated broadcast facility.



## Viewpoint #2

**Kahu (Reverend) Charles Kauluwehi Maxwell, Senior**

(These comments reflect Rev. Maxwell's point of view and do not reflect the position of any organization.)

Why do we native Hawaiians get angry whenever something is put on the top of Haleakalā? From ancient times the mariners used Haleakalā as a point of reference. When they looked up and saw the star called Hōkūpaʻa, they knew they were in Hawaiian waters. They continued in a northerly direction and the first thing they saw was Haleakalā if they were coming down the Keala i Kahiki channel. “Keala i Kahiki” means the road to Tahiti.

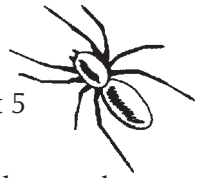
Maui, Molokaʻi, Lānaʻi, Kahoʻolawe were all one island thousands of year ago. This was called Maui Nui a Kama, the Greater Maui. Papa, the earth mother and Wakea, the sky father, created the islands, and Haleakalā is the *piko*, the navel, the center of Maui Nui a Kama. It is the cultural center point of all these islands that were once joined.

Pele, the Goddess of Volcanoes, was born in Tahiti. She tried to find a permanent home by digging craters with her magic ʻōʻō (digging stick) throughout the Pacific. Reaching the Hawaiian Islands, she tried to make a home on each island from the northern islands of Nihoa and Necker to the Big Island of Hawaiʻi. She dug the crater of Puʻumōiwi on Kahoʻolawe and created eruptions at Kanaio. She continued up the south rift of Haleakalā and left a chain of cinder cones which led directly into the crater of Haleakalā. For a while, she resided in Haleakalā but was not satisfied, so she ventured to Hāna by way of Kaupō, causing a great eruption that ran down to the sea. A great battle ensued between Pele and her sister Nā-maka-o-ka-haʻi, the goddess of the sea. Pele was killed and her bones were scattered on a cinder hill called Ka-iwi-o-Pele in Hāna. Being a goddess, Pele manifested herself and went to the island of Hawaiʻi, where she presently resides at Hale-maʻu-maʻu crater on Kīlauea.

There are shelter sites in Haleakalā crater with carbon dates that show human habitation from the third century. Haleakalā has so many ancient burials. I was privileged to have discovered an *akua kāʻai*, which are remains of ancient kings that were wrapped in sennit (Hawaiian rope made from coconut husk fibers) and placed in a *heiau* (Hawaiian temple). It had spears next to it, and carved carrying sticks. It is considered as one of the most sacred religious items for our people. Everyone that was buried in Haleakalā was considered royalty. No commoner would be buried up there.

For our people it is considered the “pathway to call the sun” and that is where the sun lives. The placing of a telescope on top of the mountain ruins the spirituality of the entire mountain. There is a *heiau* on one of the ridges in the crater where the demigod Maui prepared his sennit to lasso the sun so his mother’s tapa could dry. After the telescope was built, the Air Force wanted to put several sensors on the ridges of the crater. I told them that they could not because of the sacred *heiau* that were there. They did not believe me, so they flew me up in a helicopter, and on the three-thousand-foot precipice, there stood the *heiau*. When I was 18 years old, I had climbed up the cliff to see it. My *kupuna* told me about the *heiau*. I also showed them several others. They did not place any sensors on the crater ridges.

Poliʻahu is the goddess of the snow and when Hawaiians see the snow on Haleakalā, they say that Poliʻahu is in residence and is covering the bones of our *kupuna*. That’s why when you build a telescope that can be seen from all over, it is an actual blight on the sanctity of Haleakalā. For us it is not just a mountain, it’s a sacrilege to desecrate it—like moving the antennas one mile and bringing them down to Kalepeamoā. Kalepeamoā



is named for a chicken demigod that lived in that area, so the whole mountain is for us a very spiritual place. It is a sacrilege to plow it, to take out rock as they did when building the Air Force telescope.

Why step on our culture for the betterment of science? We are the only group of people that can spiritually link to Haleakalā. Every island is named, every river, every gulch is named after Hawaiian gods and goddesses, but people don't respect that. Can you imagine that thousands of years before our people came here in the third century these names existed? It was told to our ancestors by our prophets and spoken about in chants. We did not "stumble" on Hawai'i like Captain Cook did. Our ancestors knew it existed. When they came here in their double-hull canoes, they came equipped with their families, animals, plants, gods and goddess. They lived here thirteen hundred years before being discovered by Western man. They were strong robust people and the world's greatest ecologists.

When Captain Cook arrived, it actually was the end of our race, as we died by the thousands from the common cold and other Western diseases. Now we are fighting this new disease called "progress" that wants to eliminate us and our Hawaiian spirituality and values. We all must bend to ideas of the West and science that threaten our existence in these islands as we know it. Our lands were taken against our will, and we are doggedly trying to hold on to our culture. They want to change it to be like wherever they're from.

Why can't we work together? Why aren't we consulted? As our late King Kalakaua said in his book, *Myth and Legends*: "Soon we will be only footprints in the sand and our song will not be heard."



*Viewpoint #3*

**Mary M. Evanson, President  
Friends of Haleakalā National Park**

*(These comments on the Draft Environmental Assessment were submitted on behalf of Friends of Haleakalā National Park.)*

We have reviewed the subject document and offer the following comments:

It is stated in the Draft Environmental Assessment (DEA) that both Kalepeamoia and Keonehunuhune [a lower elevation site located on Ulupalakua Ranch] are viable sites for this project from the technical standpoint. We feel that there will be significant adverse environmental impacts if Kalepeamoia is developed, while at the lower site of Keonehunuhune adverse impacts would be negligible. Therefore, we strongly urge that Keonehunuhune or some other site lower on the southwest rift zone be used for this project instead of Kalepeamoia.

The only development now on the summit area of Haleakalā outside the national park has been within lands set aside for Haleakalā Observatories and lands down to and including the FAA low site. This proposed tower project is well outside this developed area, one mile down the mountain and could very well spark demand for other projects in the area. This southwest rift zone is remote wilderness that is little known but worthy of protection either under the state's Natural Area Reserve System or the National Park Service.

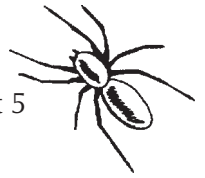
The entire mountain of Haleakalā is a visual, cultural and geological resource that must continue to be recognized as being of great significance and vital to our visitors and our local residents. The northeast side of Haleakalā supports dense native forests with heavy rainfall. The southwest rift zone has sparse vegetation and little rainfall but spectacular views and volcanic eruptions up and down the rift zone created a line of colorful cinder cones and pit craters. This

alpine rockland provides visual enjoyment of geological features found nowhere else. The scenic beauty and interpretive possibilities of this area are unlimited and should be preserved. The proposed 199-foot towers would be the highest structures on the mountain; they would be visible from Kula and all of central Maui from Kihei to Ha'ikū. They will greatly impact the values and the environment of Haleakalā and especially the southwest rift zone.

There are concerns about the endangered dark-rumped petrel that must be addressed more fully. The four 199-foot towers would be in the vicinity of petrel nesting burrows and in the flight paths of the birds. Petrels will die, and since the facility will not be manned, any downed injured birds cannot be saved. We should be doing all we can to save what few native birds are left; erecting four 199-foot towers in their path is not the way to go. Only a cursory survey was done for invertebrates and plants; this is not adequate. The DEA states that the road to the site will not be improved, and yet heavy construction equipment of all kinds will be needed. There needs to be more detailed information regarding public health and safety relative to radiation in the area.

In addition, we have serious concerns about the impacts of alien species—such as the Argentine ant, which threatens numerous native insect species, as well as such rare plants as the federally-protected Haleakalā silversword, with extinction—which may be introduced to the national park and surrounding areas by use of the Kalepeamoia site. The unique and fragile biotic character of the Kalepeamoia area is underscored by Haleakalā National Park's designation as a globally important "Man and the Biosphere"





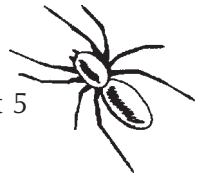
Reserve. Because it is impossible to guarantee that harmful alien species will not be introduced by construction and other human-related activities with respect to this project—and such introductions are potentially permanent and have irreversible consequences—we propose that an alternative site be used, one which is less unique and biotically sensitive.

Alien species issues (introductions, impacts, and control/eradication if introduced) are not adequately addressed in the DEA. Alien species which may be inadvertently introduced could affect invertebrates, plants, birds, and other organisms, some of which are federally protected species. Adequate measures for prevention of alien species introduction must be detailed and these measures included in contractors' specifications for all aspects of the proposed project. Also, contingency plans should be devised to ensure funded eradication measures in perpetuity in the event of any breach of preventive measures (i.e., in the event of an alien species introduction). These issues must be acknowledged and adequately addressed by formal, legal documenta-

tion and prior to any decisions being made about the selection of any site for this proposed project.

If Kalepeamoā continues to be the site of choice a full analysis of the project through an Environmental Impact Statement must be done. In addition to the aforementioned concerns, questions which must be addressed include:

- How will construction be arranged without destroying the existing loose cinder Skyline Drive?
- How big an area might be affected by the project?
- Will radiation impact the petrels?
- Skyline Drive is an official *Na Ala Hele* trail and is used by hikers, mountain bikers, and hunters; how might they be affected by radiation?
- The area is now one of absolute silence except for an occasional helicopter; will there be noise from the facility (such as humming)?



## Viewpoint #4

### Virginia Parsons, Broadcast Consultant

*(These comments are based on those submitted by Ms. Parsons on the Draft Environmental Assessment. They do not reflect the position of any organization.)*

I am in full support of the proposed antenna farm project on the summit of Haleakalā and have personally visited the site. The proposed project will help broadcasters become more efficient.

In addition to the transmitters that can be relocated so they no longer interfere with operations at the Haleakalā Observatories, there are transmitters located at lower elevations that could be moved to the new site. All of the FM transmitters could be moved out of the local communities where they are now housed. From the new site, they would require less electricity to operate and have better “line of sight” to carry their signals to the public. Up top, there would be less reception interference than there is at the lower elevations where the towers are currently located. The proposed site will be built away from local housing communities in an area unlikely to be inhabited by development. This avoids future conflicts between development and the transmitters.

More importantly, the reach of the broadcast signal from the proposed summit site will be an enhancement to our civil defense program as it will allow broadcasters to reach almost all points throughout the state in an emergency. No other site offers such coverage. Unfortunately, disasters happen, and we must be prepared to protect the public the best we can. Not looking beyond the moment would be a crime, as lives would surely be lost without effective broadcast coverage.

There are no alternatives to the proposed summit site that would provide adequate coverage to the population at large. It appears the only reason that there is any conflict regarding this proposed summit site deals with a “bad” business decision made by a Lahaina broadcaster to pour \$400,000 of concrete onto Ulupalakua Ranch, apparently to

construct an antenna farm on private property so as to avoid the normal state bid process for a landlord at the top of Haleakalā.

Even if this concrete disaster were remotely viable, television broadcast would work only with towers 750 feet high. Even with such high towers, engineers believe they would still lose coverage at this lower-elevation site. And we have not yet determined what kind of coverage these facilities would offer as broadcasters transition from the current analog technology to new digital broadcast technologies. Some radio stations would be able to reach the city in which they are licensed to broadcast from the Ulupalakua site. Others, such as those serving or slated to serve Makawao and Ha‘ikū, would not.

Given the choice between 750-foot towers equipped with flashing strobe lights, and the shorter, less obtrusive towers that would be needed at the higher elevation, I think I’ll take four short (199-foot) sticks. These will have underground wiring. (The proposed summit site area has already been dug and lined with fiber optics.) I doubt that the facility on top of Haleakalā will be the eyesore that was built on Erdman’s ranch.

Realistically, if the nay sayers were to truly evaluate the good from the evil, the facts abound that in an emergency, broadcast transmission is a Godsend, a life-saving warning, a comfort, as well as necessary survival information, which would surely outweigh any opportunistic protest. We need to reach beyond the current reflection and see the real reason for the rivalry—and it has nothing to do with the good of the land or the people ... only rental incomes.



*Viewpoint #5*

## **Dr. Donald Mickey, Solar Astronomer, University of Hawai'i Institute for Astronomy**

*(These comments reflect Dr. Mickey's point of view and do not reflect the position of any organization.)*

Astronomers work on high mountain tops in order to have the clearest view possible of objects in the sky. The quality of "seeing" at Haleakalā is not quite as good as it is on Mauna Kea because the prevailing northeast winds heat up as they blow across the crater, causing a small amount of air turbulence around the lip of the crater. But Haleakalā has some advantages over Mauna Kea. The weather is more reasonable on Haleakalā, the road access is better, and because of its lower elevation there is more oxygen available in the atmosphere. An elevation of 10,000 feet is manageable for most people, while 14,000 feet is uncomfortable for most.

Mauna Kea is one of the three best astronomy sites in the world. But Haleakalā is not far behind in the ranking. Astronomers consider it to be among the top five percent of sites for ground-based astronomy.

High up on the slopes of Haleakalā is also a good place to locate television and radio transmitters. From there, the transmitters can cover most of Maui, windward O'ahu, and the Kohala coast of Hawai'i. And, as is true for the observatories, the transmitters are easy to reach by road for the people who need to maintain and repair them.

The problem is that increasingly powerful radio and TV transmitters placed on top of Haleakalā cause interference in the electronic cameras systems in the telescopes and degrade the quality of observations. Both the number and the radiated power of the transmitters has increased over time, so that they now are not only unsightly but could represent a health hazard for people walking the nearby roads. At the same time as the radio frequency interference (RFI) from the transmitters has increased, astronomers have also

become dependent on very sophisticated electronic equipment to do their work. In the past, electronics at the observatories was limited to motors that moved equipment. Now, most equipment relies on high speed computers and sensitive electronic detectors. The more sensitive the instrument the more it is affected by the transmitters.

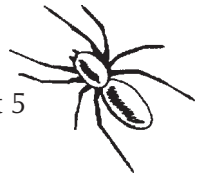
The conflict between the broadcast facilities and the observatories has been growing for many years. Now there is an opportunity to move the transmitters to another location that will work well for them and reduce RFI at the observatories. In 1996, the U.S. Congress passed the Telecommunications Act, mandating a nationwide transition from analog to digital broadcasting. During the next several years, television broadcasters will be putting digital transmission in place while continuing to transmit conventional analog television programming. Eventually, analog will be phased out.

Since the broadcasters will have to replace their transmitters to accommodate digital transmission, this is a good opportunity to relocate the transmitters from their scattered locations around the observatory complex to a different, well-designed location. This move could benefit everyone concerned: The broadcasters would benefit from a modern facility with comparable broadcast coverage to the present site but better separated from people. Astronomers would benefit from dramatically decreased RFI due to a greater distance between the observatory and the transmitters. The mountain itself would shield the observatories from some of the signal put out by the transmitters. Visitors to Haleakalā National Park would also benefit because there would be less visual impact in the summit area.



The International Astronomical Union has set standards for the acceptable level of radio frequency interference measured outside an observatory doing optical or infrared observations. The total allowable interference, summed over all frequencies, is two microwatts per square meter. At Haleakalā Observatories, we have measured in excess of 184,000 microwatts per square meter.

When local broadcasters comply with the Federal Communication Commission requirement to simultaneously transmit in both digital and analog for several years, we expect the RFI levels to more than double at the observatories. This is obviously a problem we need to solve, and moving the transmitters is a good solution.



## Viewpoint #6 Iokepa Nae'ole

(These comments reflect the viewpoint of Mr. Nae'ole and do not reflect the position of any organization.)

Through my ancestral connection to these islands, I am bound to its stewardship. By nature as well as by trade, I am a conservationist and stand opposed to any form of *commercial* development, large or small. Periodically throughout my lifelong residency here on Maui, I would ask, "When will it stop?" When will there be enough hotels to satisfy the supposed demands of the visitor industry? When will we finally have enough retail outlets to supply our population with the modern amenities that fill our homes? How many television and radio stations will be sufficient to entertain the masses? How much of our precious land and natural resources will we *all* ultimately sacrifice in the name of technology and progress?

As a native Hawaiian I have always questioned, and will always question, the reasoning and the logic used by developers when they seek government approval for their ventures. I am forever skeptical of their motivations. I detest the reality of development and refuse to accept the lack of control that native Hawaiians have in regulating land use. Rationalization has become my way of dealing with it. Okay, maybe a new resort will provide much need employment for the island. And a new Home Depot will not only provide jobs, but may also stir up some competitive prices. I may need a new recliner so that I can thoroughly enjoy all 200 channels of commercial advertisement, interrupted occasionally by an episode of Gilligan's Island. So there you have my stance on development in general: too much already.

So what about the Haleakalā Observatories and the radio frequency interference caused by transmitters located nearby? We know that the two facilities are technically incompatible neighbors and one of them has to move. So the proposal is to relocate and consolidate existing

broadcast facilities to an area where RFI will no longer affect the mission of the observatories. I partially agree with this proposal. I feel that the scientific activities conducted at the summit should continue and that all efforts be made to eliminate the source of RFI from the summit area. Does this belief come into conflict with my own cultural values? How, you may ask, do I feel about the existence of such a facility that many Hawaiians view as a desecration of sacred land? While I do agree that the summit is a culturally and ecologically sacred place and that the construction of the structures there has no doubt caused extensive environmental change, I also value knowledge and learning.

Hawaiians have always been a race of stargazers. The *kilohōkū* of ancient days would spend many nights perched upon the highest summits gazing, searching, pondering, and prophesying. Without physically departing our *honua* they would take journeys of the mind into the depths of space, seeking answers to questions still asked, and yet to be answered, by modern science and technology. While I regret the loss of habitat for native species, and while I resent the restricted access to the sacred summit area, I know that Hawaiians themselves were explorers whose culture was dynamic and innovative, and accepting of progress in the name of exploration.

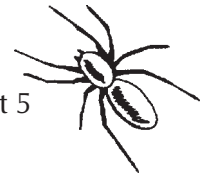
Exploitation, on the other hand, is a subject less open to compromise. Commercial exploitation of land for financial gain is a foreign concept to the Hawaiian culture. Whether it is a resort built on beachfront property or a snorkel tour mooring drilled into the ocean floor, it is considered an affront to nature and culture. As far as I'm concerned, there are only two transmitters that should exist on the mountain: Hawai'i Public Television and National Public Radio. The rest are just *'ōpala*. We waste entirely too much time



inside, insulated from the real world, while watching “The Real World.” I wouldn’t even blink if all of a sudden there were only one station to look at or listen to. Channel surfing would become a thing of the past. Call it a radical point of view; I don’t care. So why don’t we tear down the existing transmitters from the summit area and build two new ones in the Kalepeamoā area?

Getting back to reality, we know this idea won’t fly. We all know money speaks louder than logic. The project will proceed as planned, and transmitters will proliferate at an even more rapid

pace. The mountain will suffer another lesion that many of us will witness every day, quickly to be forgotten with the opening jingle of the KGMB News at Six. In my life I have learned to understand progress. Building more stuff doesn’t mean progress. It just means we’ll have more stuff. Do we need all of this junk? One day my TV will be put to its best use as I throw it over the side of my canoe as an anchor over my best fishing spot.



Viewpoint #7

**Donald W. Reeser, Superintendent  
Haleakalā National Park**

(These comments on the Draft Environmental Assessment are a summary of those submitted on behalf of Haleakalā National Park.)

Perhaps the greatest factor protecting the unique cultural and natural resources of Haleakalā National Park is the large extent to which the park is surrounded by conservation lands. The conservation land base comprised of the park, State Forest and Natural Area Reserves and private reserves provides an effective unfragmented area for perpetuating Hawaiian ecosystems. It also buffers the serious threat of invasions of alien plants and animals. The proposed project site is on State Forest Reserve/conservation land, and will increase the footprint of development on the summit ridgeline.

The Draft Environmental Assessment (DEA) is based on speculation in a number of areas that call into question the viability of the proposed site and raise a number of environmental concerns. Any development in the buffer of conservation lands around the park poses a potential threat of new alien invasions to park ecosystems.

A series of issues raised by the proposal follows:

1) The need for the project is to provide broadcast service antenna facilities which will not cause unacceptable levels of radio frequency interference at Haleakalā Observatories (HO). The DEA states: “Relocation of the broadcast facilities to Kalepeamoia *should* decrease RF energy at the observatories to an acceptable level.” It appears that the outcome of the preferred alternative is uncertain, yet the DEA fails to consider the Keonehunehune site as a viable alternative even though it states with certainty of the Keonehunehune site:

“No special beam shaping of the transmitting antennas would be required since the terrain shielding and path loss *would* reduce signal at the observatories to levels will below the International Astronomical Union recommended limits.” In contrast, the Kalepeamoia site would require special directional antenna patterns to reduce RFI at the observatories.

- 2) Page S-9 states, “The antenna facilities will cover less than one acre, and consequently their construction will have minimal impact on natural resources.” Figure III-1 illustrates the footprint at more than four acres. Thinking more broadly, the visual impact of the proposed site will be many thousands of acres.
- 3) The DEA fails to consider the unique high-elevation Haleakalā aeolian environment as a sensitive area. Construction in the area of the Haleakalā Observatories Complex has degraded the fragile environment, reducing the diversity of plants and insects there. This should be considered a prediction of impacts of the proposed project.
- 4) The DEA makes no definite provision for moving the existing antennae towers and other structures if a new facility is built. In V-21, 5.2.1.4 the DEA notes: “It is *anticipated* that the manmade structures in the saddle facility would *eventually* be removed.”
- 5) The proposed site is a known ‘ua‘u flyway. This Endangered Species is vulnerable to flying into foreign objects such as towers, fences, and buildings. The entire broadcast facility would be a “foreign object” into which the ‘ua‘u may fly.



Also, the DEA states in section 5.2.6.1, “There would be *no* unshielded lights to disorient birds in flight.” But in S-5, the section on avifauna, the DEA states, “It is *assumed* that the Federal Aviation Administration (FAA) will not *require* lights on antenna towers.” It appears that antennas on the proposed site would present an aircraft hazard. If lights are required on the antennas by the FAA, navigational and collision hazards to ‘ua‘u would be increased. Visual impacts would be extended to the night sky.

- 6) Based on previous construction projects in the summit area, we know that shipments of construction materials and equipment need to be inspected by a qualified biologist prior to shipment, as well as before access is permitted through the park. Portions of the hydraulic systems of the Air Force Advanced Electro-Optical System telescope were manufactured in killer-bee-infested areas of Texas, for example. Once on Maui, accidental

alien importation could cause environmental havoc before being detected. The DEA’s recommendations for monitoring access and the construction site for at least a year as are important mitigation measures, as inspections will not detect 100 percent of alien organisms. Any construction project in a Hawaiian conservation area poses potential impact to native ecosystems from alien invasions.

If this DEA were to pass public review, inspections both prior to shipping and before transit through the park would be required to attempt to mitigate threats from alien introductions. Increasing the footprint of development on the Haleakalā summit ridgeline sets a precedent for future development of public conservation lands adjacent to Haleakalā National Park. The National Park Service strongly urges that an alternative site to Kalepeamoā be selected for the facility. The potential impacts to the park are too great.



# Different Views in the News



The Honolulu Advertiser

# HAWAII

Friday, November 27, 1998  
City Desk: 525-8090

ADV 11/27/98

## Haleakala antennas debated

TV, astronomy among issues

By Edwin Tanji

Advertiser Maui County Bureau

**HALEAKALA, Maui** — The chilly, bleak summit of Haleakala just doesn't have enough room for everyone who wants to be there.

Air Force and University of Hawaii observatories track the sun, satellites, asteroids and stars. Television and radio antennas broadcast signals across the state. Hikers and tourists admire panoramic views and austere geologic features. Native Hawaiians see a spiritual center of their culture.

distances in space, observing activity on the sun and tracking satellites in Earth orbit.

Even before the observatories were built, Haleakala also was home to a cluster of broadcast antennas that send television and radio signals to homes on Maui, the Big Island and Windward Oahu.

For FM transmitters, Haleakala's summit is an ideal antenna site, capable of sending line-of-sight signals 200 miles away to Kauai. But radio waves that powerful — as much as 22,000 watts — also overpower astronomical instruments just a few hundred yards away.

Researchers studying data on computer screens are find-

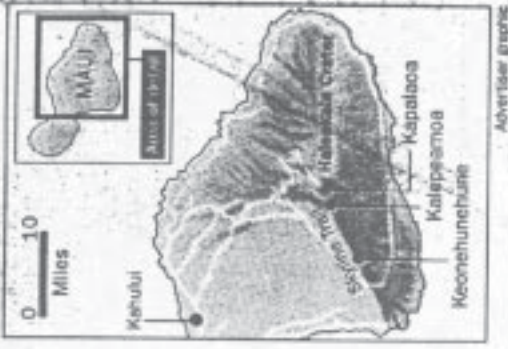
ing television programs popping up instead, consultant Charles Fain said.

"The radio waves can overwhelm everything else," he said.

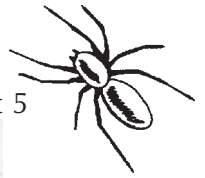
"It's like when you turn on a vacuum cleaner and your television is on. The electronic discharge from that electric motor causes interference with the television," he said.

The potential addition of antennas is an issue for UH scientists, because research has grown more sophisticated. The scientists must measure radio waves from distant stars and satellites, as well as opt-

See Antennas, Page B4



Advertiser graphic



# Antennas: Plans debated for future of Haleakala summit

A 11/27/98

FROM PAGE B1

cal images.

"The real problem is that there are 80 applications for transmitters on top of Haleakala, in addition to the seven or eight that are there now," said Mike Maberry, Maui manager for the Institute for Astronomy.

Maberry said a coordinated broadcast facility is needed that could accommodate the demand for new transmitters, but would not interfere with the work of astronomers. But Kalepeamoa, a potential broadcast site at 9,400 feet identified in the environmental assessment, intrudes on a pristine natural area and has brought objections from hikers and Hawaiians.

"To me, it's just one of the most beautiful places on Maui," said Mary Evanson, a Sierra Club supporter and a founder of the Friends of Haleakala National Park.

## Panoramic views

Kalepeamoa is a ridge line where the Haleakala "Skyline Trail" runs down the southwest slope, offering hikers panoramic views of the Big Island, Lanai, Molokai and Maui, with closeup looks at craters and cinder cones that illustrate Maui's geologic history.

"It's just super special," Evanson said. It would be marred by 190-foot-tall antennas clustered over a five-acre site, with fences and sheds to protect transmitters and generators, she said.

Evanson conceded that she doesn't understand the broadcast technology. But her resolve is firm.

"It's very complicated and it's very difficult for us to understand. All I know is that Kalepeamoa is much too precious. We cannot let anyone develop it," she said.

## 'Spirituality of Haleakala'

Charles Maxwell, the Pukalani Hawaiian cultural specialist, said he would prefer the antennas stay where they are, and the Institute for Astronomy forego further development at the summit.

"Every building, every structure they put up there, to me, is ruining the spirituality of Haleakala from what it was 1,000 years ago," Maxwell said.

He said he has seen evidence of traditional burials around the summit, probably of high-ranking ali'i. Volcanic formations are seen as indicators of the presence of the Hawaiian goddess Pele, who legend says made her home on Haleakala before moving to Kilauea on the Big Island.

There are remains of an ancient heiau on the ridge above Kapalaoa that Maxwell said is associated with the demigod Maui, who is said by legend to have forced the sun to slow down by netting it from Haleakala.

Moving the antennas to Kalepeamoa would intrude on yet another sacred area, while allowing the Institute for Astronomy to plan more observatories on the summit, he said. He said he doesn't oppose the antennas, just the proposed site.

Evanson said she would support moving the antennas to a site at Keonehunehune, at 4,400 feet of elevation. An antenna farm for radio transmitters already has been located there.

But television engineers said the lower site would cut off a large number of television viewers. From Kalepeamoa, television and radio transmissions can reach half of the Big Island, central Maui to Huelo and Windward Oahu from Makapuu to Laie. From Keonehunehune, the signal would be cut off to parts of Kona, would reach only to Pauwela on Maui and would be lost to all but Makapuu on Oahu.

Dave Moore, director of engineering for KHON-TV, said any site below 8,000 feet "doesn't work." Television signals are sent from Honolulu to Haleakala to be rebroadcast back to the areas blocked from the Honolulu transmitters, he said.

## Matter of cost

At lower elevations, he said, the West Maui mountains would block the signal from Honolulu. Stations would have

to install additional transmitters at an extra cost that might not be justified for a relatively small part of a station's audience, he said.

Keith Aotaki, director of engineering for KHNL-TV, said the Haleakala antennas also relay their television signal to the Big Island to transmitters that cover East Hawaii. Moving the Haleakala antenna to a lower elevation could mean moving transmitters on the Big Island, which could prove too costly, he said.

But not moving the antennas would affect Haleakala's role in scientific research. UH officials say without the interference from broadcast antennas, the Haleakala summit could attract three to five new scientific facilities over the next 20 years.

## Economic benefit

New observatories would put millions of dollars in construction spending into Maui's economy, while operating expenditures would run at \$1 million to \$5 million a year.

None of it can happen until a decision is made on the antennas, Maberry said. He said the Institute for Astronomy committed itself to preparing a master plan for its 18-acre "Science City" parcel at the summit.

But the institute cannot prepare a master plan until it knows what is possible, he said. If the antennas stay in place, they will affect the plans, he said.

"It will determine what type of equipment we may be able to put up there. With some facilities, we still will be able to do certain types of science," Maberry said.

The final environmental assessment found no significant impact for an antenna facility at Kalepeamoa.

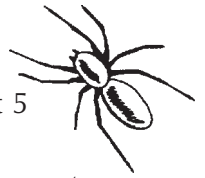
But the public has until Monday to comment on the finding and on whether a full environmental impact statement should be prepared.



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# Questions About the Viewpoints

- 1) Which viewpoint were you assigned to read?
  
- 2) Do you think the person whose viewpoint you read would be in favor of:
  - moving the transmitters to Kalepeamoā?
  
  - moving the transmitters somewhere, but not to Kalepeamoā?
  
  - not moving the transmitters at all?
  
  - studying the alternative further?
  
  - another course of action? (If so, what?)
  
  - allowing other types of development in the summit area? (For example, in the past there have been proposals to build a tram to take visitors up the mountain to the summit. Do you think this person would support this kind of proposal?)
  
- 3) What are the person's main arguments for their position?



4) Look at the following list of value systems. Which of these systems do you think are the most influential to this person's point of view? (There may be more than one.) Explain your answer.

Aesthetic	focus on appreciation of intrinsic and subjective qualities, such as the beauty of an area
Cultural	related to maintaining the practices and attitudes of a culture
Ecological	concerned with living things and the function of ecological systems
Economic	related to the exchange of goods and services
Educational	concerned with benefits derived from learning
Egocentric	focus on self-satisfaction and personal fulfillment
Legal	concerned with the law and its enforcement or application
Recreational	related to the use of leisure time

*From 'Ō'hia Project, Grades 7-8, Bernice Pauahi Bishop Museum and Moanalua Gardens Foundation, Honolulu, 1992, p. 284. Adapted from Ramsey, J.M., H.R. Hungerford, and T. Volk, "A Technique for Analyzing Environmental Issues," The Journal of Environmental Education, Vol. 21 No. 1, 1989.*



*Bonus Activity*

# What Goes On at the Observatories?

## ● ● ● In Advance *Student Internet Research Assignment*

- Assign Student Page “Surf the Net to Research the Haleakalā Observatories” (pp. 36-38) and Student Page “Research Instructions and Questions” (pp. 39-40) as homework.

## ● ● ● Class Period One *Learning From Each Other’s Research*

### Instructions

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- 1) Ask one student to give a brief report on his or her research, then invite other students who researched the same facility to add details. Continue until you have covered all of the facilities. If there is time left at the end of class, begin a class discussion using the journal ideas listed below.

### Journal Ideas

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- Does knowing more about the research and work that is performed at the Haleakalā Observatories change your opinion about the proposal to relocate the broadcast facility to another location where radio frequency interference will not be a problem? Explain your response.
- Think of other ways that people might have understood or explained the phenomena being studied at the Haleakalā Observatories without the benefit of scientific inquiry and the instrumentation housed in the observatories. Describe one or more of these different ways of understanding the world.
- Describe at least one way in which you think the work being done at the Haleakalā Observatories will (or does) benefit people.

### Assessment Tools

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- Student Page “Research Instructions and Questions”
- Participation in class discussion
- Journal entries



# Surf the Net to Research the Haleakalā Observatories

You've heard of "Science City," haven't you? It's the collection of observatories and other research facilities that sit clustered together near the summit of Haleakalā. Many people call it "Science City," but the scientists who work there prefer to use another name: "Haleakalā Observatories." This more official and respectable name is also an accurate reflection of what goes on in this group of white and metallic domes and a scattering of other buildings.

"What DOES happen up there?" you might ask. You are going to find out by doing your own research on the Internet. Most of the research facilities have excellent websites that can help you learn about what goes on behind the sign that says, "Authorized Access Only."

The Haleakalā High Altitude Observatory Site is—you guessed it—home of the Haleakalā Observatories. It is just downhill from the *Pu'u'ula'ula* (Red Hill) Overlook near the mountain's summit. The 18-acre site was given to the University of Hawai'i by the State in 1961. This land must be used for observatory purposes only or it must be given back to the State.

Since 1961, several facilities have been built on this site to study and track all kinds of things having to do with the sun and moon, the earth's atmosphere, satellites, and other objects traveling through space.

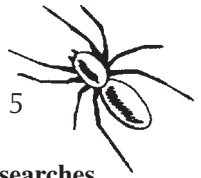
## Your Assignment

From the following listing of the observatories on Haleakalā, you will select one or more to research on the Internet. In addition to the observatories listed, there are other facilities proposed or being built at Haleakalā Observatories, some of which are mentioned on the Haleakalā Obser-

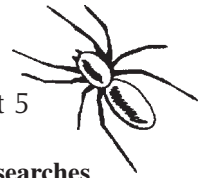
vatories website at <[www.ifa.hawaii.edu/haleakala](http://www.ifa.hawaii.edu/haleakala)>. (These include the Faulkes telescope, Solar C telescope, and MAGNUM project.) As progress continues toward making these facilities operational, there is likely to be more information available about them on line and they could make interesting Internet research projects as well.

## Other Internet Resources

- Personal web pages of researchers. Some of the observatory websites have links to researchers' web pages that describe the research they are doing.
- Glossary of terms related to the sun and solar research at <[solar-center.stanford.edu/gloss.html](http://solar-center.stanford.edu/gloss.html)> or <[www.hao.ucar.edu/public/education/glossary.html](http://www.hao.ucar.edu/public/education/glossary.html)>.
- "Ask a Solar Physicist," where students can direct solar questions to the staff of the Stanford University Solar Center, <[solar-center.stanford.edu/ask-solar/asksolar.html](http://solar-center.stanford.edu/ask-solar/asksolar.html)>.
- Educational materials on solar physics, National Solar Observatory, <[www.sunspot.nao.edu/](http://www.sunspot.nao.edu/)>.
- Government departments that collect and archive data from heliospheric projects. Each has a website: National Space Science Data Center (NSSDC), National Oceanic and Atmospheric Administration (NOAA), and World Data Center (WDC).



Facility name and website	Brief description of research	Related websites	Keywords for searches
<p><b>Air Force Maui Space Surveillance Complex (MSSC) at</b> &lt;ulua.mhpcc.af.mil&gt;</p>	<p>Space surveillance activities are conducted here for the U.S. Department of Defense.</p>	<p>Air Force Research Laboratory home page, which provides more information about the Maui Space Surveillance Complex at &lt;ulua.mhpcc.af.mil/amos.html&gt;</p> <p>Overview of space surveillance at &lt;www.spacecom.af.mil/usspace/space.htm&gt;</p>	<p>-Adaptive optics -Air turbulence -Space surveillance</p>
<p><b>Cosmic Ray Neutron Monitor Station at</b> &lt;ulysses.uchicago.edu/NeutronMonitor/neutron_mon.html&gt;</p>	<p>A neutron monitor detects incoming energy from cosmic rays emanating from sources including solar flares.</p>	<p>“Listening for Cosmic Rays,” an overview of cosmic rays, their significance, and how they are detected at &lt;www.bartol.udel.edu/~neutronm/listen/main.html&gt;</p> <p>Overview of cosmic rays and how they are monitored at &lt;www.ngdc.noaa.gov/stp/SOLAR/COSMIC_RAYS/cosmic.html&gt;</p> <p>Neutron monitor information, links, and general solar weather information, Solar-Terrestrial Division of the Izmiran Institute (Russia) at &lt;helios.izmiran.rssi.ru/cosray/main.htm&gt;</p>	<p>About the kinds of observations done at the monitor station: -Cosmic rays -Particle astrophysics -Air showers -Space weather</p> <p>Why scientists measure cosmic rays: -Stellar nucleosynthesis -Diffuse gamma-ray emission -Anti-particles</p> <p>Techniques for studying cosmic rays from the ground: -Neutron monitors -CASA/MIA -Fly’s eye</p> <p>Spacecraft with instruments that measure cosmic ray intensity and related conditions in space. Each has a website: -Ulysses -Voyager -ACE -IMP-8 -SMAPEX -WIND -POLAR -GEOTAIL</p>



Facility name and website	Brief description of research	Related websites	Keywords for searches
<p><b>Lunar and Satellite Ranging (LURE) Observatory at</b> &lt;koa.ifa.hawaii.edu/Lure/&gt;</p>	<p>Laser equipment is used to track the distance between the earth and the moon and to track satellites.</p>	<p>A brief history of laser (lunar) ranging at &lt;almagest.as.utexas.edu/~rlr/history.html&gt;</p> <p>An introduction to lunar laser ranging at &lt;wwwrc.obs-azur.fr/cerga/laser/laslune/englishintro.htm&gt;</p> <p>Article on lunar laser ranging written to commemorate the 30<sup>th</sup> anniversary of the Apollo 11 mission at &lt;www.xs4all.nl/~carlkop/ap11.html&gt;</p>	<p>-Satellite laser ranging -Lunar laser ranging</p>
<p><b>Mees Solar Observatory at</b> &lt;koa.ifa.hawaii.edu&gt; and &lt;www.ifa.hawaii.edu/research&gt;</p>	<p>Optical instrumentation housed here is used to observe the sun. Research topics include solar flares, magnetic fields on the sun, and solar oscillations.</p>	<p><i>A Primer on the Space Environment</i>, with basic information about solar phenomena and their relationship to earth at &lt;sec.noaa.gov/primer/primer.html&gt;</p> <p>SpaceWeather.com, a Nasa site with daily updates of sunspots, solar flares, near Earth asteroids, aurora, meteor showers; streaming video, text, at &lt;http://spaceweather.com/&gt;</p> <p><i>Space Weather Today</i>, with information about the earth/sun relationship and how solar phenomena affect earth at &lt;windows.engin.umich.edu/spaceweather/&gt;</p> <p>Overview of “helioseismology,” the study of wave oscillations in the sun at &lt;soi.stanford.edu/results/heliowhat.html&gt; or &lt;helios.tuc.noao.edu/helioseismology.html&gt;</p>	<p>-Solar flares -Solar oscillations (or low frequency solar oscillations) -Solar cycle -Solar physics -Helioseismology -Precision solar photometry (or PSPT)</p>



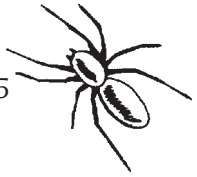




3. Pick one kind of research or work that happens at this observatory. What do scientists hope to learn? How do they apply, or hope to apply, what they learn?

4. List one interesting fact that you learned about this observatory or the research that is done there.

5. List two questions you have about this research.



# Draft Environmental Assessment

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