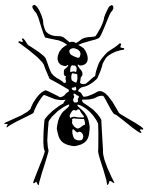


Activity #6

Wiliwili Gall Wasp Invasion

Length:
One class period with optional homework assignment

Prerequisite Activity:
None

Objectives:
- Trace the path of the 2005 wiliwili gall wasp invasion on Maui using real-life data.
- Identify vectors ad pathways that facilitate the spread of invasive species.
- Devise strategies for stopping an invasive pest.
- Predict the efficacy of control strategies, based on existing and plausible environmental factors.

Vocabulary:

biological control (or biocontrol)
deciduous
dormancy
Erythrina gall wasp (EGW)
vector

● ● ● Class Period One: *Exploring the Gall Wasp Invasion on Google Earth*

In Advance

This exercise requires access to Google Earth (free software available for download at www.earth.google.com) and the Wiliwili Gall Wasp Hoike.kmz file (included with this curriculum and available for download at www.hoikecurriculum.org). It's best to pre-load computers with the program and file, rather than use class time to do so.

Ideally students will work in small groups at their own computers as you lead them through the lesson, using a projector and screen. If that's not possible, a single computer and projector will suffice.

Prior to teaching the lesson, open Google Earth. If you're using the software for the first time, take a few moments to learn how zoom, pan, search, etc. using the "Navigating Google Earth" tutorial available at www.earth.google.com. It is best, though not necessary, to use Google Earth while connected to the Internet.

Explore the Wiliwili Gall Wasp Hoike.kmz file.

Provided Map Layers:
- Initial infestations (8 sites documented by Hawai'i state entomologist, Mach Fukada)
- Pu'u o Kali (best example of native *wiliwili* forest in Hawai'i and the *Erytoma erythrinae* biological control release site)

- *Wiliwili* habitat (area on Maui where native *wiliwili* trees can be found)
- Wind lines (Maui's prevailing wind directions)
- Major roads
- Ports of entry
- Agricultural land (where nonnative wiliwili trees were used as windbreaks)
- Erythrina Gall Wasp Survey (50 infected tree sites documented by the Maui Invasive Species Committee)
- Tanzania (country where state entomologist Mohsen Ramadan located the gall wasp's natural enemy: *Eurytoma erythrinae*.)

Materials & Setup

- Computer (s)
- Projector
- Wiliwili PowerPoint.ppt file (included in this curriculum or available for download on www.hear.org/hoike)
- "Wiliwili PowerPoint Script" (Teacher background, pages xx)
- Google Earth software (available for free download at www.earth.google.com)*
- Wiliwili Gall Wasp Hoike.kmz file (included in this curriculum or available for download at www.hoikecurriculum.org)*

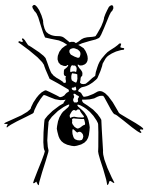
*loaded onto each computer

Instructions

Students will trace the path of the 2005 wiliwili gall wasp invasion on Maui and respond to the challenge of controlling the pest using real-life data: wind patterns, roads, ports of entry, presence of nonnative host trees, and life cycle of the native *wiliwili*. Their task is to control the vectors to stop the gall wasp's spread.

1) Present the "Wiliwili PowerPoint" to class, using the Teacher Background "Wiliwili PowerPoint Script."

2) Homework assignment: Have students strategize how to assist the spread of *Eurytoma erythrinae*, taking the new environmental factors into account. Things to consider:
   - Non-native erythrina trees are gone and no longer serve as a breeding ground. How will this affect the speed of the spread?
     A: It will likely be slower, and not cover as much ground in residential and farming areas.
   - Which season would be best for encouraging spread?
     A: Late winter or spring, when the trees have new leaves. The period of dormancy, when there are few leaves, would not be a good choice.
   - How might heavy rain or drought affect the new wasp's spread?
     A: Rain would encourage new plant growth, which would in turn encourage gall wasp reproduction. The predatory wasp would find plenty to prey on. Drought would have the opposite effect; spread would be slower.



- Where is the best location to release the wasp?
  A: Wherever there is still a large population of Erythrina species showing signs of infection— in particular, Puʻu o Kali.
- How can each vector be incorporated into the release plan?
  - Cars can be used to intentionally transport the wasp to other areas across the island.
  - Planes and boats can be used to intentionally transport the wasp to other islands, such as Molokaʻi and Lānaʻi.
  - Wind can be taken into consideration. Biologists might choose to release wasps in a breezy area where the insects are likely to be blown to the next grove of trees.

Journal Ideas

- When the gall wasp invasion started on Maui, some people suggested eliminating the thousands of nonnative wiliwili trees to prevent them from acting as a host for the wasp. Others thought that destroying the trees was too extreme. What are your thoughts? Do you think people would have been willing to cut down their trees? Why or why not?
- Do you think eliminating the false wiliwili trees would have ultimately changed the progression of the invasion? Why or why not?
- What could Maui County or the State of Hawai'i do to protect itself from similar invasions in the future?
- Which elements of the wiliwili gall wasp's journey can we predict? Which elements do we have no control over?

Assessment Tools

- Answers from brainstorming session
- Participation in group discussion
- Homework assignment

Further Enrichment

- Change the elements of the gall wasp invasion; have students devise control strategies for a hypothetical insect that crawls, or is a foot long, or burrows underground.
- Have students predict the success of the introduced biological control, *Eurytoma erythrinae*, based on new factors: the elimination of the nonnative wiliwili trees as hosts, the longer lifespan of the predatory wasp, rainfall, wind direction, etc.

Teacher Background

Wiliwili PowerPoint Script

We're going to use Google Earth to explore a real-life scenario that happened on Maui in 2005. You'll have the data used by biologists and you're going to face the same challenges they did after discovering a wiliwili gall wasp invasion.

Introduce Google Earth.

[[Slide 1: screen shot of Google Earth]]
Type your school's name into the "fly to" search box in the left hand navigation bar. A list of choices will appear.

Clean up navigation box & practice navigating.

[[Slide 2: screen shot of Google Earth with arrows pointing to "fly to" box and folder listing school choices.]]
De-select the top folder, so that the checkmarks disappear. Then select your school's correct address from the list below.

Double click on the name to "fly to" your school.

Practice navigating: right and left clicks, holding and dragging mouse. Hold and drag middle roller button to tilt the view and access a horizontal plane.

Introduce Vectors

Scroll back until you can see the entire Pacific Ocean.

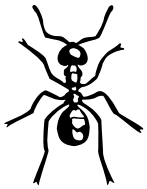
[[Slide 3: Earth]]
Hawai'i is the single most isolated large landmass in the world. We're almost 3,000 miles away from the nearest continent. Before humans came to these Islands, how did anything get here?
A: Wind, wings, and waves.

Now that humans are here, how do things get here?
A: Planes and boats.

These are vectors.

[[Slide 4: Vector (click several times)]]
What is a vector? It's an agent of dispersal, or a carrier that takes things from one place to another. Vectors can be living organisms, like birds; they can be natural phenomena like wind or waves; or they can be manmade modes of travel like planes and boats.

We're going to look at vectors on two scales: vectors that bring things to Hawai'i and vectors that transport them around the island once they're here.



- Have students name some vectors that move things around the island (eg: cars, wind, ocean currents, streams, birds, animals, humans, shipping containers, mail service, boats, planes, bicycles, stand up paddle boards)

Understanding vectors is important when you want to stop something from moving around. In 2005, land managers and biologists wanted to stop the *wiliwili* gall wasp.

Introduce *wiliwili*

[[slide 5: flowering wiliwili tree in Kenaio]]

- Have students pronounce Latin name: *Erythrina sandwichensis*.
- Discuss Latin name: *Erythrina* indicates genus, *sandwichensis* refers to the tree's native range, Hawai'i, once known as the Sandwich Isles.

[[slide 6: orange wiliwili flower]]
Wiliwili trees produce some of the most beautiful native Hawaiian flowers.

[[slide 7: ivory wiliwili flower]]
Flower colors can range from pale green and ivory to deep orange and red.

[[slide 8: two flowering wiliwili trees in mist]]
The *wiliwili* is a keystone species in the native Hawaiian dryland forest. Like the pillars that hold up a house, *wiliwili* trees are essential parts of this unique ecosystem's structure: they provide shelter and food for native insects and birds. They cycle water and nutrients into the soil. Shrubs and vines thrive beneath their shade.

Hawaiian cultural connections

[[slide 9: Hawaiian proverb ('ōlelo noe'au) "When the wiliwili blooms, the sharks will bite."]]
The ancient Hawaiians were excellent observers of the natural world. They recognized connections between plants, animals, and seasonal changes. According to this *'ōlelo noe'au*, or Hawaiian proverb, sharks bite when the *wiliwili* blooms. What does that mean? Anecdotal reports say that in late summer/fall, when the trees are flush with flowers, sharks are busy mating and are more active close to shore—therefore more likely to mistake a human for a snack.

[[slide 10: forceps fish]]
Hawaiians compared the color and movement of falling *wiliwili* leaves to the forceps fish. As leaves turn yellow and flutter to the ground, they resemble the native reef fish.

[[slide 11: seeds]]
The *wiliwili* tree gets its Hawaiian name from its twisted seed pods. "*Wiliwili*" means twisted.

[[slide 12: seed lei]]
Wiliwili seeds are gorgeous—ranging from dark purplish brown to scarlet. They are used to make long-lasting seed *lei* that are valuable to hula practitioners.

[[slide 13: surboards]]
The wood of the *wiliwili* tree is especially buoyant. Hawaiians used it to carve surfboards and canoe *ama*.

[[slide 14: Kenaio]]
Wiliwili trees grow in some of the world's harshest conditions: the hot, shadeless, lava plains of South Maui. They provide essential habitat for native insects and shrubs.

[[slide 15: deciduous]]
What is the word in the middle?
A: deciduous.

We don't have many deciduous plants in Hawai'i. The term refers to plants that seasonally lose their leaves, such as the New England trees famous for their fall foliage. Their leaves change color, then fall off so the trees can go dormant through the harsh winter months. These deciduous trees are regulated by temperature.

The *wiliwili* tree's deciduous cycle is regulated by moisture and is on an opposite schedule: it goes dormant during summertime. In late winter and spring, it is in full foliage, soaking up as much rainfall as it can. Then the leaves turn yellow and start to fall, resembling the forceps fish. In midsummer, the tree withdraws into itself to survive the hot, relentless summer. Then, in late summer it bursts forth in an explosion of colorful blossoms. Next, in autumn, the tree is covered in seeds. Then winter comes and the cycle starts again.

[[slide 16: stretch marks]]
Wiliwili maximize the rainy season by holding water like camels. Their trunks expand. During the dry season, the trunks shrink again, leaving stretch marks on the bark.

[[slide 17: non-native Erythrina species]]
- Ask students how many of them remember the trees lining Mokulele Highway.

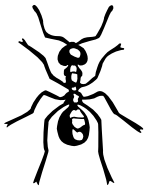
People imported nonnative Erythrina species to use as windbreaks and landscaping elements. These trees were planted all over the island and played a large role in the gall wasp epidemic.

Introduce the gall wasp invasion

[[slide 18: gall wasp damage]]
These *wiliwili* leaves and stems are covered in lumpy, gnarly galls. Gall wasps are insects that lay eggs in plant tissue, causing galls to form around the developing larvae. When the larvae hatches, it eats the surrounding plant material before emerging. A mysterious gall wasp has attacked these *wiliwili* trees.

[[slide 19: gall wasp]]
- Have students say *Quadrastichus erythrinae* aloud. What does erythrinae signify*?*

A: a dependence on erythrina species.



[[slide 20: Discovery news article]]

- Select students to read one paragraph each aloud. (It's best if they stand up and face their classmates.) Instruct students to take out pen and paper and listen for two things in the article: 1) where the wasp came from and 2) how it is moving around on Maui.

Where did it come from?
A: It was discovered in Singapore, and in Taiwan and Oʻahu, before coming to Maui.

How is it moving around on Maui?
A: wind, automobiles, shipping crates.

Work with Google Earth layers

- Return to Google Earth. Tell students to select "Queen Kaʻahumanu Mall" under "Initial Infestations. Double click to fly there.

[[slide 21: Queen K screen shot]]

- Have student read the caption.

Next select "Kahului Mall," directly below "Queen Kaʻahumanu Mall."

- Have student read caption.

- Instruct students to scroll back, for a view of all of Kahului.

- Ask them what is nearby these ports. How might a new species have arrived?

A: Kahului harbor and airport.

Select all items in the "Initial infestations" folder. These are real GPS points. Where are the two furthest points?
A. Maʻalaea and Kīhei.

Select "Puʻu o Kali" (orange square below "Initial Infestations"). Double click to fly there.

- Have student read caption.

Explore the terrain, the *puʻu*. Explain the significance of this spot—the best example of native Hawaiian dryland forest in the world.

It's your job is to protect this place from the infestation. Like the article said, you have $100,000 to respond to this emergency. The challenges: controlling the vectors. What are they? How does the wasp travel? (As students answer, instruct them to select "wind lines" "major roads" and "ports of entry" on Google Earth.)

It's your job to come up with creative, effective ideas to counteract each vector.

There's another challenge, in addition to these vectors. The large, island-wide population of nonnative erythrina trees serves as a breeding ground for the infestation. If there hadn't been any of these trees near the airport and harbor, the gall wasp would have nothing to feed on when it arrived. It very likely would have died without spreading further.

Select "ag lands." This represents the area on the island where farmers have planted nonnative erythrina trees as windbreaks.

Select "*wiliwili* habitat." This represents the area where native wiliwili trees are found growing in the wild. This area can also serve as a breeding ground for the infestation. However, wild trees grow sporadically—unlike the densely packed rows forming windbreaks around farms—so infestations here might not be as strong. Also, because native *wiliwili* trees lose their leaves during summer, they are less vulnerable to attack at that time.

Small Group Brainstorm

- Allow students to work in small groups for ten minutes. Instruct them to record their answers and choose a spokesperson to read them. After ten minutes, let each group present their ideas.

[[slide 22: solutions]]

- Discuss the solutions and why or why not they were adopted by Maui County.

Prune infested leaves and stems; compost under heavy plastic: Maui County tried this. Pruning infected trees involved renting heavy machinery, getting permission from landowners, and working overtime. Unfortunately, it failed. Biologists did not know much about the newly described wasp. They didn't know that it preferred young leaves. Pruning trees caused the infestation to spread even further.

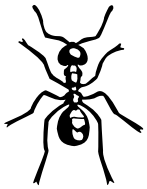
Set up roadblocks; search cars for plant material: Maui County did not try this. It would have been extremely expensive and difficult to launch, given the time frame.

Enforce airport and seaport blockades. Maui County did not try this. It would have been extremely expensive and difficult to launch, given the time frame. (Consider discussing that baggage is inspected on the way OUT of Hawai'i, but not on the way IN.)

Eliminate all nonnative Erythrina trees. Maui County did not try this, though it was actively considered as an option. It would have taken a massive public relations campaign to convince landowners to destroy their trees and do so without spreading infected materials.

Use pesticide. Biologists did try this. However, the inoculation cost $300 per tree, so it was only used experimentally, to preserve special trees.

Release natural enemy or biocontrol. The State of Hawai'i did this. Immediately upon the discovery of the pest wasp, entomologists began searching the world for its natural enemies. We'll talk more about this in a bit.



Collect seeds for seed bank. The State of Hawai‘i did this. Shortly after the discovery of the gall wasp, volunteers from all over the state began collecting seeds representing genetic diversity of the species and storing them in controlled environments in the event that the tree went extinct in the wild.

[[slide 23: Efforts Fail news article]]
- Select students to read article.

[[slide 24: Dead trees on highway]]

[[slide 25: Exploded wiliwili]]
This 300-year-old native wiliwili tree in Pu‘u o Kali exploded. During the rainy season, it stored water in its trunk as usual. Later, when new leaves formed, they were attacked by gall wasps. Without a way to respirate, or release the water, the tree burst from the internal pressure.

- Instruct students to select all the items in the “MISC survey” folder on Google Earth. Inform students that while these solutions were being enacted, MISC surveyed the island to determine the extent of the infestation. Have students read captions of some of the furthest points. (eg: Lāna‘i, Nu‘u Mauka Ranch)

[[slide 26: Students Collect Seeds News Article]]
- Select students to read article.

By October of 2006, the situation was as dire as could be. Most of the nonnative erythrina species were severely infested or had already died. Around 20 percent of the trees within Pu‘u o Kali showed signs of gall wasp damage. Biologists were facing the possibility of extinction of one the key Hawaiian forest species.

Introduce Natural Enemies

[[slide 27: Mohsen Ramadan]]
Luckily, students weren’t the only ones working to save the wiliwili. State entomologist Mohsen Ramadan was researching the gall wasp, *Quadrastichus erythrinae*. Very little was known about the pest. It had been discovered in Singapore, but it was an invasive pest there, too. No one knew where its true origin was, or how to control it. Because *Quadrastichus* was dependent on erythrina species for survival, Mohsen looked to the highest population of erythrina species in the world: Africa. While Hawai‘i has one native erythrina species, East Africa has numerous. The State of Hawai‘i sent Mohsen to Tanzania to search for natural enemies of the gall wasp.

- Instruct students to select “Tanzania.” Double click to fly there.

[[slide 28: Eurytoma erythrinae]]
Mohsen traveled through Tanzania by bus, stopping in the countryside to inspect trees for signs of gall wasp. He was successful. He found *Quadrastichus erythrinae* and several natural enemies. The most promising was another wasp.

- Have students say: *Eurytoma erythrinae*. Ask them what *erythrinae* signifies.

A: the wasp is dependent on *Erythrina* species—in this case, the *Erythrina* gall wasp.

Eurytoma erythrinae wasps lay their eggs inside the *Quadrastichus erythrinae* galls. *Eurytoma erythrinae* larvae hatch first and feed on *Quadrastichus erythrinae* larvae.

The State of Hawai‘i subjected *Eurytoma erythrinae* to numerous tests to insure it wouldn't become a new pest. When biologists were ready to release it, they were confronted with a new problem—the opposite of their first challenge—how to help the wasp spread far and fast.

- Instruct students to select "Pu‘u o Kali." Double click to fly there.

[[slide 29: Test tube release of Eurytoma erythrinae]]
Hawai‘i Department of Agriculture entomologists released *Eurytoma erythrinae* on infected trees in Pu'u O Kali in November 2008. It immediately began attacking *Quadrastichus erythrinae*, slowing the infestation down considerably.

[[slide 30: Wiliwili seeds germinating in lava]]
Galls were still found on trees, but instead of crippling the tree, they were only present in small numbers. Germinating seeds, like these two, stood a good chance of developing into future trees.

[[slide 31: Rainbow over wiliwili habitat]]
By 2011, scientists had declared the effort a success. If you'd like to enjoy the spectacular blooming wiliwili, take a drive out to Kaupō in late summer. Along the roadside you'll find trees awash in cream-colored and red blossoms.

[[slide 32: wiliwili in flower]]