# From Evolution in Isolation to Globalization

### **Overview**

Over millions of years, plants, insects, fish, and birds found their way to the Hawaiian Islands before the arrival of humans. The first Hawaiian species came here via the three W's: wind, wings, and waves. Once they arrived, these pioneer species adapted to their new home. Over time, many of their descendents transformed into altogether new species: endemic species that are native to Hawai'i and exist nowhere else on earth. As a result, Hawai'i is an unparalleled showcase for evolutionary diversity.

Scientists estimate that, prior to human contact, one new species successfully colonized the Islands every three to five thousand years, on average. That number has since skyrocketed, because of the increased traffic associated with humans. Now, between 30-50 new species find their way to the Islands every year, having originated from points all over the globe. Many of these newcomers are benign, causing no problems, but some have become serious pests: invasive species capable of disrupting the existing natural balance of native Hawaiian ecosystems.

In this unit, students learn the basics behind invasion science: what determines whether a species is native, non-native, or invasive, where many species originate, how they got here, and how they impact our native ecosystems.

### Length of Entire Unit:

6-7 class periods

# **Unit Focus Questions**

- 1) How do species colonize Hawai'i?
- 2) What factors make Hawaiian ecosystems especially vulnerable to invasion?
- 3) What are the basic concepts and definitions of invasion biology?
- 4) Where do native species come from?
- 5) Where do invasive species come from? What areas on Maui can they invade?
- 6) What is a scientific name? How are scientific names useful?
- 7) How and why do we chose certain species as icons or mascots?





### Activity #1\_\_\_\_\_ Introducing Invasives

Students answer the question "what species are native to Hawai'i?" They watch a slideshow presentation (or read an article for homework) illustrating invasive species definitions and concepts. They complete a crossword puzzle to demonstrate their understanding.

#### Length:

One class period (may be preceded and followed by homework)

#### **Prerequisite Activity:**

The Rain Forest Module Unit 3 Activity #2 "Adaptive Radiation in Rain Forest Birds" is helpful but not necessary; it may be completed after this activity for enrichment.

#### **Objectives:**

- Develop a basic vocabulary of invasive species concepts.
- Gain a "big picture" understanding of invasive threats to native biodiversity.

# Activity #2 \_\_\_\_\_ What's in a Name?

Students develop familiarity with scientific, English, and Hawaiian names for species. Exploring how and why Latin is used to describe species, students create names for fictional species. Students learn how early Hawaiians told stories to convey natural information.

#### Length:

One class period

#### Prerequisite Activity:

None

#### **Objectives:**

- Demonstrate understanding of scientific, common, and Hawaiian names for species.
- Create valid scientific names for fictional species.
- Connect Hawaiian myth or story to botanical information about a species.



# Activity #3

# Timeline

Students create a timeline to visually tell the story of how species colonize the Hawaiian Islands. Students compare the rate of successful colonization during different periods of Hawaiian history: before the arrival of humans, pre-European contact, before the advent of jet travel, and today.

#### Length:

One class period (two if students make their own materials)

#### **Prerequisite Activity:**

None

Note: This activity could be done early in the year/semester and used as a visual reference for the remainder of the school year. Throughout the Teacher Background "Rate of Introduction Script," you'll find additional Ho'ike lessons noted where relevant. You can use the timeline as a springboard into those activities.

#### **Objectives:**

- Document notable dates in Hawaiian natural history from 30 MA to present.
- Document introductions of new species to Hawai'i.
- Create a graph showing how the rate of successful colonization by foreign species has dramatically increased throughout the history of Hawai'i.

# Activity #4 \_\_\_\_\_ Where Do They Come From? Where Can They Invade?

Working with maps, students explore where invasive species in Hawai'i came from, how they got here, and what native ecosystems they are equipped to invade. Note: The cards made during this activity are necessary for the next activity, "Invasive Jeopardy."

#### Length:

One class period

## Prerequisite Activity:

None

#### **Objectives:**

- Map the origins of invasive species and indicate possible pathways to Hawai'i.
- Map which areas on Maui specific invasive species are likely to invade based on climate, elevation, and other factors.



### Activity #5 \_\_\_\_\_ Invasive Species Jeopardy

Students play a game of Jeopardy to deepen their familiarity with invasive species facts. They generate their own Jeopardy questions using cards created in Activity 4 "Where Do They Come From? Where Can They Invade," or flyers included in this curriculum.

#### Length:

One class period

#### **Prerequisite Activity:**

Invasive Species Module Unit 1 Activity #4 "Where Do They Come From? Where Can They Invade?"

#### **Objectives:**

- Investigate relationships between native Hawaiian and invasive species.
- Become familiar with invasive species, their origins and characteristics.
- Use knowledge gained to create jeopardy questions.

# Activity #6 \_\_

# Mascots, Icons, and 'Aumakua

Students consider which plants and animals are chosen to represent their school, island, state, and country, and why. They list the qualities these species emulate and consider similar native Hawaiian species as alternatives. They read an essay by Hawaiian cultural leader Herb Kane about 'aumakua, Hawaiian spirit guardians, to explore indigenous relationships to the natural world.

#### Length:

One class period

#### **Prerequisite Activity:**

None

#### **Objectives:**

- Demonstrate understanding of native and non-native species.
- Practice critical thinking skills with regard to mascot choices.
- Investigate Hawaiian cultural connections to animals.
- Develop reading comprehension.



# **Enrichment Ideas**

- Define "species." How is a species defined over time? At what point do scientists declare a descendant a distinct species from its ancestors?
- Explore the records kept by botanists who sailed with the first Western ships to visit Hawai'i.
- Investigate the debate surrounding certain Polynesian introductions, such as: coconut (*Cocos nucifera*), *Hau* (*Hibiscus tiliaceus*), and indigo (*Indigofera suffruticosa*), *pa'iki* (*Rorippa sarmentosum*). What are the arguments for and against these species arriving here without human aid? What evidence is there to support the idea that they were brought by Polynesian settlers?

# Resources for Further Reading and Research

Bloxam, Richard, Byron, George, and Calcott, Maria, Voyage of H.M.S. Blonde to the Sandwich Islands, in the years 1824-1825. John Murray, London, 1826, p. 86.

Cuddihy and Stone, *Alteration of Native Hawaiian Vegetation*. University of Hawaii Press, 1990.

Evenhuis, Neal L., *Barefoot on Lava: The Jour*nals and Correspondence of R.C.L. Perkins in Hawaii, 1892-1901, Bishop Museum Press, 2007.

Juvik, Sonia P., and Juvik, James O., *Atlas of Hawai'i*, by Thomas R. Paradise, University of Hawai'i Press, October 1998.

Nagata, Kenneth, "Early Plant Introductions in Hawai'i," *The Hawaiian Journal of History*, vol. 19, 1985.

Ziegler, *Hawaiian Natural History, Ecology, and Evolution*. University of Hawai'i Press, 2002.

State Department of Agriculture website: http://hawaii.gov/hdoa/ag-resources/history

Hawaiian Invasive Species Council Website: www.hawaiianinvasivespecies.org/hisc



# nit 1

# Activity #1 Introducing Invasives

#### Length:

One class period (may be preceded and followed by homework)

#### **Prerequisite Activity:**

Rain Forest Module Unit 3 Activity #2 "Adaptive Radiation in Rain Forest Birds" is helpful but not necessary; it may be completed after this activity for enrichment.

#### **Objectives:**

- Develop a basic vocabulary of invasive species concepts and terms.
- Gain a "big picture" understanding of invasive threats to native biodiversity.

#### Vocabulary:

Adaptive radiation
Biodiversity
Biological control
Canoe plants
Containment
Ecosystem
Endangered

Endemic Eradicate Evolution Feral Globalization Invasive Isolation Miconia Native Naturalize Natural Resource Management Ungulate

## • • • In Advance:

- Depending on your students' reading comprehension level, you can assign the Student Page "From Isolation to Globalization" as homework, or present the slideshow in class.
- Rain Forest Module Unit 3 Activity #2 "Adaptive Radiation in Rain Forest Birds" is helpful but not necessary; it may be completed afterwards for enrichment.

# • • • Class Period One: Defining Native, Nonnative, and Invasive

#### Materials & Setup

- "From Isolation to Globalization" slideshow included on the DVD and available for download at www.hoikecurriculum.org
- "Species Glossary" on the DVD

#### For each student

- Student Pages "From Isolation to Globalization" (pp. 15-19)
- Student Page "Invasive Species Crossword" (pp. 20-21)



#### Instructions

- 1) Ask students to list on a piece of paper as many examples of native Hawaiian plants and animals as they can think of.
- Discuss the definitions of native (including endemic and indigenous species), and non-native (including canoe plants, introduced, and invasive species) using Teacher Background Page "Definitions" (pp. 9-12) as guidance.
- 3) Have students read their lists in turn, writing "N" for native, "C" for canoe plant or animal, and "I" for introduced beside each item. The student with the most unique "N" listings can win a prize. Use the "Species Glossary" on the DVD included with this curriculum as a reference.
- Note: If you aren't sure which heading a particular species falls under, you can assign finding the answer to students for homework.
- 4) Present the slideshow "From Isolation to Globalization" and/or have the students the read Student Pages "From Isolation to Globalization" (pp 15-19). Spend the remainder of the class discussing the slideshow and/or reading. As vocabulary words are read, have students write the definitions down. Tell them that they will need these to complete the "Invasive Species Crossword."

5) Assign the Student Page "Invasive Species Crossword" (pp. 20-21) in class or as homework. Note: All the answers are included in boldface type in the slideshow script and the reading assignment.

6) Once they've completed the lesson, have students revisit their list and add as many native (N), canoe (C), introduced (I), and invasive (IN) species as they can.

#### Journal Ideas

- What did you learn about plants and animals you thought were native?
- Pick five of the vocabulary words from the reading and write a paragraph using all five.
- Pretend you are a seed or spore just blown in on the wind from far away. Write a story detailing your origin, your journey, and how you adapted (over millennia) to the new environment in which you found yourself.

#### Assessment Tools -

- Participation in class discussion
- Student Page "Invasive Species Crossword"
- Student's list of native, canoe, introduced, and invasive species
- Journal entries

#### Further Enrichment \_

• Show the students the film, *Miconia Threatens Maui*, included in this curriculum on the DVD and available to view at www.hoikecurriculum.org.



# Teacher Background **Definitions**

The following is a list of species categorized as NATIVE (both indigenous and endemic) (N), CANOE (C), INTRODUCED (I) or INVASIVE (IN). Consult the "Species Glossary" on the DVD for a comprehensive, alphabetized list of species that includes photos; scientific, common, and Hawaiian names; and native, non-native, and invasive status.

**NATIVE (N): a species that arrived or evolved in an area without the assistance of humans.** Native includes both indigenous and endemic species.

**Indigenous:** native to an area but not unique to that area. (Note: Outside of Hawaii, indigenous is generally considered a synonym for "native".)

#### **Plant examples:**

English	Hawaiian	Latin				
beach morning glory	pōhuehue	Ipomoea pes-caprae				
		subsp. Brasiliensis				
false sandalwood	naio	Myoporum sandwicense				
pandanus	hala	Pandanus tectorius				
staghorn fern	uluhe	Dicranopteris linearis				
	aʻaliʻi	Dodonaea viscosa				
	<i>`ilima</i>	Sida fallax				
	pūkiawe	Leptecophylla tameiameiae				
	naupaka kahakai	Scaevola sericea				

#### Animal examples:

English	Hawaiian	Latin
frigate bird	ʻiwa	Fregata minor
green sea turtle	honu	Chelonia mydas
humpback whale	koholā	Megaptera novaeangliae
Pacific golden plover	kōlea	Pluvialis fulva
spinner dolphin	naiʻa	Stenella longirostris



#### Endemic: unique to an area; native to no other place on earth.

#### **Plant examples:**

English	Hawaiian	Latin				
Hawaiian dodder	kauna'oa	Cuscuta sandwichiana				
Hawaiian poppy	pua kala	Argemone glauca				
Hawaiian raspberry	ʻākala	Rubus hawaiensis				
Hawaiian tree fern	hāpu'u	Cibotium glaucum				
lobelia		Lobelia gloria-montis				
sandalwood	ʻiliahi	Santalum haleakalae				
silversword	'āhinahina	Argyroxiphium sandwicense				
	koa	Acacia koa				
	māmane	Sophora chrysophylla				
	<i>`ōhelo</i>	Vaccinium reticulatum				
	ʻōhi'a	Metrosideros polymorpha				
	•	•				

#### Animal examples:

English	Hawaiian	Latin
Crested honeycreeper	'ākohekohe	Palmeria dolei
Hawaiian duck	koloa	Anas wyvilliana
Hawaiian goose	nēnē	Branta sandvicensis
Hawaiian hoary bat	ʻōpeʻapeʻa	Lasiurus cinereus semotus
Hawaiian monk seal	ʻīlio holoholo i ka uaua	Monachus schauinslandi
Hawaiian petrel	ʻuaʻu	Pterodroma sandwichensis
Hawaiian stilt	ae'o	Himantopus mexicanus knudseni
Maui parrotbill	kiwikiu	Pseudonestor xanthophrys
Short-eared owl	pueo	Asio flammeus sandwichensis
	'apapane	Himatione sanguinea
	ʻi <sup>ʻ</sup> iwi	Vestiaria coccinea



# **CANOE** (C): Polynesian introductions brought to Hawai'i by the first human settlers.

#### Plant examples:

English	Hawaiian	Latin
banana	mai'a	Musa spp.
breadfruit	'ulu	Artocarpus altilis
candlenut	kukui	Aleurites moluccana
coconut palm	niu	Cocos nucifera
kava	'awa	Piper methysticum
shampoo ginger	ʻawapuhi kuahiwi	Zingiber zerumbet Sm.
sweet potato	'uala	Ipomoea batatas
taro	kalo	Colocasia esculenta
ti	kī	Cordyline fruticosa

#### Animal examples:

English	Hawaiian	Latin
Polynesian rat	ʻiole	Rattus exulans
Polynesian pig	pua'a	Sus scrofa
chicken	тоа	Gallus gallus domesticus
dog	ʿīlio	Canis lupus familiaris
gecko	moʻo	Hemidactylus frenatus

**INTRODUCED (I):** a species that does not originate from the particular area where it is **observed.** Synonyms: alien, exotic, introduced.

#### Plant examples:

English	Hawaiian	Latin					
avocado		Persea americana					
bird of paradise		Strelitzia reginae					
mango		Mangifera indica					
pineapple		Ananas comosus					
plumeria		<i>Plumeria</i> spp.					
ten cent flower	pua kenikeni	Fagraea berteroana					
Animal examples:							
English	Hawaiian	Latin					
wallaby		Petrogale penicillata					



# **INVASIVE (IN):** a nonnative species that directly preys upon or outcompetes native

**species for resources.** (Note: even though these species are invasive problems in Hawai'i, some have been here long enough to gain Hawaiian names.)

Plant examples:

	:	
English	Hawaiian	Latin
banana poka		Passiflora mollissima
fireweed		Senecio madagascariensis
fountain grass		Pennisetum setaceum
gorilla ogo		Gracilaria salicornia
kahili ginger	kāhili	Hedychium gardnerianum
miconia		Miconia calvescens
pampas grass		Cortaderia jubata/selloana
red hook seaweed		Hypnea musciformi
strawberry guava	waiawī	Psidium cattleianum
giant salvinia		Salvinia molesta

#### Animal examples:

English	Hawaiian	Latin
veiled chameleon		Chamaeleo calyptratus
coqui frog		Eleutherodactylus coqui
goat		Capra aegagrus hircus
little fire ant		Wasmannia auropunctata
mosquito		<i>Culex</i> spp.
Norway rat		Rattus norvegicus



# Teacher Version Invasive Species Crossword Answers

1 I	s	0	L	A	Т	2 I	0	N														
						N										3 A						
						Т										D					4 E	
				5 C		R				6 E	R	A	D	I	с	A	т	E			V	
				0		0										Р					0	
				N		D										Т					L	
		7 G		Т		U				8 N			9 I	N	D	I	G	E	N	0	U	S
		L		A		С				A						V					Т	
10 B	I	0	D	I	V	Е	R	S	I	Т	Y					11 E	Ν	D	E	М	I	С
		В		Ν		D				I						R					0	
		A		М						V		12 F				А					N	
		L		13 E	Ν	D	А	Ν	G	E	R	E	D			D						
		I		Ν								R				I						
		Z		Т							14 N	А	Т	U	R	А	L	I	z	15 E		
		A				16 U		17 M				L				Т				с		
		Т				Ν		I					18 I			I				0		
	19 B	I	0	L	0	G	I	С	A	L	С	0	Ν	Т	R	0	L			S		
		0				U		0					V			Ν				Y		
20 C	А	N	0	E	Р	L	А	Ν	Т	s			А							s		
						A		I					s							Т		
						Т		А					Ι							E		
						E							V							М		
													Е									



#### Teacher Version

## **Invasive Species Crossword Answers**

- 1. Isolation: the condition of being solitary, remote, not subject to frequent introductions of new species
- 2. Introduced: a non-native plant or animal species
- 3. Adaptive radiation: the rapid development of many species from a single ancestral population (two words)
- 4. Evolution: genetic changes occurring in a population over time
- 5. Containment: a resource management strategy for keeping an established pest from spreading to new areas
- 6. Eradicate: to completely eliminate
- 7. Globalization: the development of an increasingly integrated global economy marked especially by greater international travel and exchange of goods
- 8. Native: a species that arrived or evolved in an area without the influence of humans
- 9. Indigenous: native to an area
- 10. Biodiversity: the various species of plants and animals in an environment
- 11. Endemic: unique to a particular area; native to no other place on earth Biological control: a method of mitigating the effects of an invasive species by releasing a natural predator from the species' native range into the environment
- 12. Feral: escaped from domestication and living in the wild, usually applied to animals
- 13. Endangered: in immediate danger of becoming extinct
- 14. Naturalize: to begin reproducing in the wild; said of non-native species that are becoming established
- 15. Ecosystem: a community of living organisms and the nonliving environment they occupy
- 16. Ungulate: hoofed mammal
- 17. Miconia: a fast-growing tree with large leaves, native to Central and South America; one of the worst invasive species in Hawai'i
- 18. Invasive: a non-native species that directly prey upon or outcompete native species for resources
- 19. Biological control: a method of mitigating the effects of an invasive species by releasing a natural predator from the species' native range into the environment it has invaded (two words)
- 20. Canoe plants: plants brought with the Polynesian wayfarers, also called Polynesian introductions (two words)

# From Isolation to Globalization



Photo courtesy of NOAA National Oceanic and Atmospheric Administration

The Hawaiian archipelago is the most remote high island group on the planet. Approximately 2,400 miles away from the nearest continent, the Hawaiian Islands arose as volcanoes from a hotspot on the ocean's floor. (The newest Hawaiian island,  $L\bar{o}$ 'ihi, has yet to break the sea's surface.) After these islands emerged and cooled, how were they populated with plants and animals?

The first **native** Hawaiian species arrived here without the help of humans, via the three Ws: wind, wings, and waves. Birds flew and fish swam here, perhaps swept off course by storms. Seeds, spores, tiny snails, spiders, and insects were carried in the muddy feet and feathers, and digestive tracts of birds, blew over in strong gusts of wind, or drifted here atop ocean debris.



Spiders travel by ballooning—sending threads of web up into the air and getting carried up into the jet stream. Illustration by Shannon Wianecki Soft-skinned amphibians didn't stand a chance of surviving this arduous journey. Reptiles and land mammals couldn't make it either. As a result, Hawai'i has many thousands of native insects but only two native mammals. Do you know what they are? One swims, the other flies. (Answer on the last page.)

Activity #1

**Invasive Species Unit 1** 

Scientists estimate that a new species successfully established itself in the Hawaiian Islands once every three to five thousand years on average. After a plant, bird, or insect found its way here, it had to settle in, survive, and reproduce.

The Hawaiian Islands offered an assortment of terrains and climates with potential to nurture a particular colonizer — ranging from sunny beaches to dry, desert-like lava plains to mist-drenched rain forests and snow-cappedmountains. Each of these **ecosystems** supports a unique community of living organisms.

#### Evolution and Adaptive Radiation

The environmental pressures and opportunities of their new home caused many of the Hawaiian archipelago's first species to adapt and change. Over tens of thousands of years, some of the



original pioneers' descendents evolved into separate species, distinct from their ancestors. **Evolution** results from genetic changes occurring in populations over time. How does it work? With each generation, accidental, genetic mutations confer a benefit to a species. The mutation allows the species to live longer and produce more offspring, who in turn display the mutation. Soon the "mutation" becomes the new norm.

In the Hawaiian forest, birds with a genetic mutation for long, curved beaks were better able to reach the nectar of tubular flowers than those with short, straight beaks. On the summit of Haleakalā, shrubs with silver, hairy leaves could best resist the intense sunlight.



To thrive in the Hawaiian environment, species slowly adopted new characteristics and jettisoned others. Since ancient Hawai'i lacked most predatory mammals, defenses against them were no longer needed. As a result, raspberries lost their sharp thorns, mints lost their mint oil, and large ducks and geese lost the ability to fly. When a group of descendents becomes substantially different from its ancestor, it is considered a new species. These new species are **endemic** to Hawaii. They evolved here and are found nowhere else on earth.

Some pioneer species evolved into not just one but many new species. This phenomenon, called **adaptive radiation**, happens when a species' descendants take advantage of multiple environments. For example, a Eurasian rosefinch arrived in Hawai'i about five million years ago. Over many generations, its descendants developed different beak shapes to occupy a slightly different niche, or ecological role. Some had long, curved beaks for sucking nectar, others had short beaks for foraging for small seeds, and still others had thick, parrot-like beaks for prying grubs from dead wood. An estimated 52 species of Hawaiian honeycreepers evolved from that single ancestral finch.

Hawai'i was uniquely suited to support evolution and adaptive radiation. Because of the Islands' extreme isolation, species could evolve without repeated introductions of new genetic material. They also had many, diverse ecosystems to occupy. Because of this, scientists consider Hawai'i an unparalleled showcase for the study of evolution.



Hawaiian sailing canoe. Painting courtesy of Herb Kāne.

#### Humans Arrive—Along with the First Invasive Species

Against this backdrop, the first humans landed in the Islands about 1,000 years ago. The Polynesian voyagers traveled here in seagoing canoes, and brought plants and animals with them. The thirty-odd plant species they brought are known as Polynesian introductions, or **canoe plants.** 



While not native, they have special cultural status; they were critical to the survival of the first Hawaiians and continue to be culturally important.

In general, these plants did not have a major impact on the native environment of Hawai'i, as most of them did not readily disperse into the wild on their own. Neither did the animals the early Hawaiians brought; relatively tame dogs, chickens and Polynesian pigs stayed within the villages—with one exception: the Polynesian rat. If you don't count humans, the rat was first **invasive species** to reach Hawai'i.

Invasive species are non-native, or alien, species that directly prey upon or outcompete native species for resources. They tend to mature quickly and aggressively take over new areas. The Polynesian rat met these criteria dramatically. It preyed upon seeds, birds, and bird eggs, literally transforming landscapes and contributing to the extinction of numerous endemic Hawaiian species.



Photo courtesy of Wikimedia Commons/karenwhimsy

In 1778, when foreign ships starting calling on Hawai'i, alien species began arriving en masse. Some species were brought intentionally; others came as stowaways. Some, like the canoe plants, did not cause much harm. Others jumped ship and immediately started wreaking havoc on the existing natural communities. Diseases carried by mosquitoes, such as avian malaria, further devastated the native forest bird population. Hawaiian honeycreepers had no resistance to the foreign disease. **Ungulates** (hoofed animals, such as cattle, sheep, and goats) caused considerable damage when set free in natural areas. They ate native herbs, shrubs and trees, and tore up the forest's blanket of mosses and ferns with their hooves, creating muddy wallows—perfect conditions for breeding mosquitoes.

Hawaiian plants that had long ago abandoned their ancestors' built-in defenses against mainland predators were extremely vulnerable. Many native species became rare, surviving only in steep gulches and cliff faces where hungry goats and cows could not reach them. Even there they faced competition from aggressive new weeds.

These rapid and dramatic changes to the natural environment of Hawai'i drove many of its native species to extinction. Many others are considered endangered: in immediate danger of becoming extinct. Hawai'i is now known as the "extinction capitol" of the United States.

#### Defending our Natural Resources

To prevent further losses, government agencies such as the State of Hawai'i, National Park Service, and private organizations such as The Nature Conservancy, work hard to protect the precious environmental resources of Hawai'i. Natural resource management projects include fencing areas to keep feral (wild) ungulates out, replanting rare native plants, controlling the most damaging invasive plants and animals, and establishing and enforcing rules against the import of new pests.

Today, between twenty and thirty new species successfully colonize the Islands every year, originating from all points of the globe. While many of these newcomers are benign, causing no problems, some have become serious pests: invasive species capable of disrupting the natural, dynamic balance of native Hawaiian ecosystems.



Miconia, a fast-growing tree native to Central and South America, is considered one of the worst invasive species currently invading Hawaiian rain forests. A serious pest in Tahiti, miconia aggressively spread through the native forest there, driving fifty endemic Tahitian plant species to the verge of extinction. When miconia was discovered in an East Maui botanical garden in 1991, conservationists recognized the danger. Volunteers from many different agencies banded together to prevent it from spreading here. This led to the eventual creation of the Hawaiian Islands' invasive species committees (ISCs). Each county in the state of Hawai'i now has a team of people devoted to combating alien pests.

In the best possible scenario, invasive species are stopped at the border, before they reach Hawaiian soil. Prevention is the least expensive, most effective method for dealing with pest species. Early detection is the next best option. When species is discovered soon after its arrival, before it has had the opportunity to naturalize, or begin reproducing in the wild, it can be effectively controlled. In these relatively rare cases, a species can be eradicated, or removed completely from an environment.

Unfortunately, miconia was detected around thirty years too late for eradication on Maui. Birds had already spread its seeds far beyond original plantings, into the rain forest. Unless discovered early, pests become too widespread and resource managers must settle for containment—keeping an established pest from spreading to new areas.

Field crews now go out regularly to pull miconia plants. Helicopters spray herbicide on larger plants from the air before they produce seeds.

Containment is expensive. Unless natural resource managers can employ another strategy, the grueling work of containing miconia and other invasive pests will be a perpetual, major expense for communities to bear. Other strategies do exist. From the time that miconia was discovered invading the Pacific Islands, scientists have been researching the feasibility of biological control: using natural predators from a pest's native habitat to slow the spread and lessen the damaging effects of an aggressive invader. Researchers have identified both a fungus and a stem-boring weevil that attack miconia. Ideally, these and other biological controls will slow the plant's unchecked growth, preventing it from dominating native Hawaiian forests.



Sam Akoi Sr. uproots a miconia tree in the Hana rainforest. Courtesy of Maui Invasive Species Committee

Biological controls do not eliminate a pest, nor are they a quick fix. Scientists spend years carefully researching and testing a potential biological control agent before it is approved for release. They select species that will only attack the desired target.

Ultimately, protecting the Hawaiian Islands' natural environment will require a combination of strategies. There is still much worth protecting. Hawai'i still boasts the highest percentage of endemic land and marine species in the world. Considering its small landmass, the Hawaiian archipelago contributes disproportionately to global biodiversity, a collective term for all of the unique species on the planet.





For many millions of years, life on these islands evolved in isolation. Native Hawaiian plants, insects, birds, and marine species developed mutually dependent relationships over long stretches of time. Now, because of globalization, the modern development of a worldwide economy, complete isolation is impossible. New species currently arrive regularly. Some will become pests; others won't. Without human enterprise, these pests never would have found a way to these remote islands. Meanwhile, many native species continue a sad march towards extinction.

Stewardship can help. While we can't take Hawaii back to the pristine landscape it was prior to human contact, we can decide how we want to affect its future.

\*Answer from page one: The two native Hawaiian mammals: *`īlio holo i ka uaua*, the Hawaiian monk seal and *'ōpe 'ape 'a*, the Hawaiian hoary bat.



Photo courtesy of Shannon Wainecki



Photo courtesy of the National Oceanic and Atmospheric Adminstration

**WDENT PA** 

# Invasive Species Crossword

1				2											
											3				
														4	
			5			6									
		7				8			9						
10											11				
								12							
			13												
							14						15		
				16	17										
									18						
	19														
20															



#### Down

- 2. non-native; brought from elsewhere
- 3. the development of many species from a single ancestral population (2 words)
- 4. genetic changes occurring in a population over time (usually accompanied by physiological and morphological changes)
- 5. a resource management strategy for keeping an established pest from spreading to new areas
- the development of an increasingly integrated world economy marked especially by greater international travel and exchange of goods
- 8. a species that arrived or evolved in an area without the influence of humans
- 12. escaped from domestication and living in the wild
- 15. a community of living organisms and the nonliving environment they occupy
- 16. hoofed mammal
- 17. a fast-growing tree with large leaves, native to Central and South America; one of worst invasive species in Hawai'i
- 18. a non-native species that directly preys on or outcompetes native species for resources

#### Across

- the condition of being solitary, remote, not subject to frequent introductions of new species
- 6. to completely eliminate
- 9. native to an area
- 10. the various species of plants and animals in an environment
- 11. unique to a particular area; native to no other place on earth
- 13. in immediate danger of becoming extinct
- 14. to begin reproducing in the wild; said of non-native species that are becoming established
- 19. a method of mitigating the effects of an invasive species by releasing a natural predator from the species' native range into the environment (2 words)
- 20. plants brought with by the first Polynesian settlers, also called Polynesian introductions (2 words)



## Activity #2

# What's in a Name?

Length:

One class period

**Prerequisite Activity:** None

#### **Objectives:**

- Demonstrate understanding of scientific, common, and Hawaiian names for species.
- Create valid scientific names for fictional species.
- Connect Hawaiian myth or story to botanical information about a species.

#### Vocabulary

Genus	Root	Suffix
Organism	Scientific name	
Prefix	Species	

# • • • Class Period One: Learning About Names

#### Materials & Setup\_

• "Species Glossary" on the DVD

#### For each student

• Student Pages "What's in a Name? Roots, Prefixes and Suffixes" (pp. 26-30)

#### Instructions\_

- 1) Ask students what they know about their own names: what do their first, middle, and last names mean? What language are they from? Why did their parents choose these names? Where did the names originate?
- 2) Set a timer and have students list all the plant, animal, or insect species they can think of in two minutes' time; list English, Hawaiian, and Latin names.
- 3) Pass out the Student Pages "What's in a Name? Roots, Prefixes and Suffixes." Allow students to work on their own, then go over the answers in class.

#### Journal Ideas\_

- If you could name a species, would you choose to honor someone or describe the nature of the species? Explain your decision.
- Some non-native species—even some invasive species—have Hawaiian names. For instance, *kāhili* ginger is a beautiful but highly invasive plant that was given a Hawaiian name for its showy



Activity #2

Invasive Species Unit 1

flower heads, which resemble the royal feather  $k\bar{a}hili$  of ancient chiefs. Strawberry guava is an invasive tree responsible for displacing more native forest than any other species and it continues to invade. People love its tasty fruits and call it by the Hawaiian name *waiawī*. Do you think the use of Hawaiian names to describe invasive species is appropriate? Why or why not?

- Write a story, using the *naupaka* legend as an example, to explain the origins of your first and last name.
- Why was Latin chosen as the scientific language? Investigate and write a paragraph explaining who decided on Latin, when, and why.

### Assessment Tools\_

- Participation in class discussion
- Student Page "What's in a Name? Roots, Prefixes and Suffixes"
- Journal entries

\*Thanks to Joan Yoshioka, who contributed the foundation for this lesson.



# Answer Key What's in a Name? Roots, Prefixes, and Suffixes

Many plant and animal species have more than one name. Plants and animals in Hawai'i often have at least three—a scientific name, a Hawaiian name, and at least one English name.

# Scientific Names

Scientists around the world use Latin words to name living organisms. They use these ancient, "dead" languages to communicate with each other, regardless of their native tongues. If a Hawaiian biologist names a plant, scientists in Japan, England, and Bolivia can understand the name. Scientific names are universal.

Scientific names usually have three parts:

- 1. a **prefix** that precedes or goes before the word
- 2. a **root**, or the main part of the word
- 3. a suffix that goes at the end of the word

This English word has three parts: precooked.

- 1. What is the prefix? pre
- 2. What is the root? cook
- 3. What is the suffix? ed

List three common prefixes of English words and give their meanings. See next page for examples

When naming organisms, scientists use a binomial (bi – "two," nomial – "name") system. Humans are Homo sapiens, which means "wise man." The term Homo is the genus name. The word sapiens is the species name. The **genus** is always capitalized, but the **species** name is not. They are both always italicized or underlined.

The native Hawaiian plant below is *naupaka kahakai*. Circle the correct spelling of its scientific name:



a) Scaevola sericea b) Scaevola Sericea c) *scaevola sericea* d) *Scaevola sericea* 

What is the genus name of *Scaevola sericea*? <u>Scaevola</u>

What is the species name of *Scaevola sericea*? <u>sericea</u>



Sometimes, an organism is given a name that describes its characteristics. For example, the genus name of *Scaevola* comes from the Greek word scaevus meaning left-handed or awkward, perhaps in reference to the "awkward" appearance of the plant's half-flower. The species name probably refers to the plant's sericeous (long, slender, silky) hairs growing on its leaves and branches. At other times, a plant is named to honor someone. For example, the endemic *Scaevola gaudichaudii* was named to honor Charles Gaudichaud-Beaupre, a French botanist who collected plants in Hawai'i in the 1800s.

#### Prefixes

a(n) – without bi – two endo – inside exo – outside hemi – half macro – large mono – one penta – five quad – four tri – three uni – one alb - white brach - arm caudum – tail cephal - head dactyl - finger dendro - tree gastro – stomach gnath – jaw homo – same hydro – water ichthyes – fish mana - hand melano – black morph - form osteo - bone pod – foot pseudo - false ptero - wing stoma – mouth tricho – hair

Roots

#### Suffixes

aceus – resembling ensis – country or place of origin fer – to carry or bear florus – flowered folius – leaved iscus – leaser issimus – very ous – full of osma – fragrant phage – eater



What would be an appropriate scientific name of a three-footed arm-eater?

#### Tripod brachophage

Illustration by Brooke Mahnken

Many, many native Hawaiian insects have yet to be discovered and named. What would you name a newly discovered insect, if you had the choice? Use the above list to name three fictional organisms and give their meanings.

#### Any reasonable combination is acceptable.

Pick the name you like best from your list and draw the invented organism below. Label and explain the features that will help it get nourishment and protect it from predators.



# What's in a Name? Roots, Prefixes, and Suffixes

Many plant and animal species have more than one name. Plants and animals in Hawai'i often have at least three—a **scientific name**, a Hawaiian name, and at least one English name.

# Scientific Names

Scientists around the world use Latin words to name living **organisms**. They use these ancient, "dead" languages to communicate with each other, regardless of their native tongues. If a Hawaiian biologist names a plant, scientists in Japan, England, and Bolivia can understand the name. Scientific names are universal.

Scientific names usually have three parts:

- 1. a **prefix** that precedes or goes before the word
- 2. a **root**, or the main part of the word
- 3. a **suffix** that goes at the end of the word

This English word has three parts: precooked.

- 1. What is the prefix? \_\_\_\_\_
- 2. What is the root?
- 3. What is the suffix?

List three common prefixes of English words and give their meanings.

1. \_\_\_\_\_ 2. \_\_\_\_\_ 3.

When naming organisms, scientists use a binomial (bi – "two," nomial – "name") system. Humans are *Homo sapiens*, which means "wise man." The term *Homo* is the **genus** name. The word *sapiens* is the **species** name. The genus is always capitalized, but the species name is not. They are both always italicized or underlined.



The native Hawaiian plant pictured is *naupaka kahakai*. Circle the correct spelling of its scientific name:

a) Scaevola sericeab) Scaevola Sericeac) scaevola sericead) Scaevola sericea



What is the genus name of *Scaevola sericea*?

What is the species name of *Scaevola sericea*?

Sometimes, an organism is given a name that describes its characteristics. For example, the genus name of *Scaevola* comes from the Greek word scaevus meaning left-handed or awkward, perhaps in reference to the "awkward" appearance of the plant's half-flower. The species name probably refers to the plant's sericeous (long, slender, silky) hairs growing on its leaves and branches. At other times, a plant is named to honor someone. For example, the endemic Scaevola gaudichaudii was named to honor Charles Gaudichaud-Beaupre, a French botanist who collected plants in Hawai'i in the 1800s.

#### Prefixes

a(n) – without bi – two endo – inside exo – outside hemi – half macro – large mono – one penta – five quad – four tri – three uni – one

Roots alb – white brach – arm caudum – tail cephal – head dactyl – finger dendro - tree gastro – stomach gnath – jaw homo – same hydro – water ichthyes – fish mana – hand melano – black morph - form osteo - bone pod – foot pseudo – false ptero - wing stoma – mouth tricho – hair

#### **Suffixes**

aceus – resembling ensis - country or place of origin fer – to carry or bear florus – flowered folius - leaved iscus – lesser issimus – verv ous - full of osma – fragrant phage - eater



What would be an appropriate scientific name of a three-footed arm-eater?

Illustration by Brooke Mahnken


Many, many native Hawaiian insects have yet to be discovered and named. What would you name a newly discovered insect, if you had the choice? Use the above list to name three fictional organisms and give their meanings.

1.	
2.	
3.	
2.	

Pick the name you like best from your list and draw the invented organism below. Label and explain the features that will help it get nourishment and protect it from predators.

# Common Names: A rose by any other name would smell as sweet...

Some plants have several "common names." For instance, the plant known as *'awa* in Hawai'i is called *kava kava* in Vanuatu and Tonga, *ava* in Samoa, *yangona* in Fiji, and *sakau* in Pohnpei.

In other cases, a common name might refer to several different plants. Fireweed in Hawai'i is the name of a small, yellow, daisy-like pest. In North America, fireweed is the name of a lovely native purple-flowered herb.

Since common names can vary from place to place, scientists use Latin names. Also called "scientific names," they are universal, used by everyone regardless of his or her native language.

# Hawaiian Names

The ancient Hawaiians were expert botanists. Many of their names for plants and animals also contained important information about how and where the species grows. Like the scientific name, the Hawaiian name for a type of *naupaka* has two parts.

Latin: *Scaevola sericea* Hawaiian: *naupaka kahakai* 

*"Naupaka"* refers to the plant's half-flower, which represents two lovers in a legend. *"Kahakai"* means near the ocean, which is where the plant naturally thrives.

The early Hawaiians recognized that *naupaka kahakai* was related to a similar looking plant up in the mountain: *naupaka kuahiwi*. *Kuahiwi* means mountain.

Both plants bears white flowers, sometimes streaked with purple, that look as if they are missing half of their petals.

Hawaiians described the origin of the twin flowers in legend. There are several versions of the *naupaka* tale in Hawaiian folklore, but all concern lovers who are separated forever, one banished to the mountains, the other to the beach.

A legend from Kaua'i, as told by Jacob Maka of Haena, involves two lovers, Nanau and Kapaka. They broke a *hula kapu* the night before their '*ūniki* (graduation). Wrapped in their *pō'ele* cloaks, they fled across Limahuli stream, passing Waialoha Spring and Maniniholo Cave. Their angry *kumu* pursued them across the flats of Naue. Reaching Lumaha'i Beach, the lovers were separated. Nanau scaled the cliffs and Kapaka hid in the beach cave of Ho'ohila. As the *kumu* approached the cliffs, Kapaka emerged from her cave and blocked the way, hoping to give her lover time to escape. Enraged, the *kumu* struck Kapaka dead and pressed up the cliff, intent on punishing the other disobedient student. Far up the ridge, Nanau heard the screams of Kapaka and turned back to rescue his beloved. The teacher caught him at Pu'uomanu and struck him mortally. Later that same day, Lumaha'i fishermen discovered a plant, never before seen, growing on the spot where Kapaka died. The plant had fleshy

leaves and small white fruit resembling congealed tears and half a flower. Returning to Pu'uomanu, the *kumu* found another strange plant, also with half a flower, growing on the spot where Nanau died. (Source of this version: http://www.huapala.org)

Pick one of the species from the Species Glossary and research the meaning of either its Hawaiian or scientific name. Does the name contain information relating to habitat, physical characteristics, or behavior? Is the species mentioned in any Hawaiian legends? (If not, create your own story.) Present your findings to the class.

Species name:		
Meaning:		
6		
Hawaiian legend:		
- 		



# Activity #3

# Timeline

#### Length

One class period (two if students make their own materials)

#### **Prerequisite Activity**

None

#### **Objectives:**

- Document notable dates in Hawaiian natural history from 30 MA to present.
- Document introductions of new species to Hawai'i.
- Create a graph showing how the rate of successful colonization by foreign species has dramatically increased throughout the history of Hawai'i.

Note: Exercises require access to research materials, Internet, or library.

This activity could be done early in the year or semester and used as a visual reference for the remainder of the school year. Throughout the Teacher Background "Rate of Introduction Script," you'll find additional Hō'ike lessons noted where relevant. You can use the timeline as a springboard into those activities.

#### Vocabulary

Adaptive radiation	Flora	Naturalize
Atoll	Fossil	Niche
Avian malaria	Generalist	Pristine
Colonize	Genetic	Rate of introduction
Descendant	Habitat	Specialized
Ecosystem	Hotspot	Tectonic plate
Evolve	Invasion	
Extinct	Isolation	
Fauna	Millennia	

# • • • Class Period One: Creating the Timeline

#### Materials & Setup -

- Materials for the timeline's physical base (string, flagging tape, or butcher paper)
- Space large enough to accommodate it
- Teacher Background "Rate of Introduction Script" (pp. 34-40), "Timeline Cards" (pp. 41, 49-90), "Tables" (pp. 44-47)

Note: You may wish to laminate timeline and cards for durability.

#### For Each Student:

• Student Pages "Rate of Introduction" worksheet (pp. 91-92)



Instructions

1) Break students into small groups. Tell them that they will be creating a timeline to visually represent how often plant and animal species colonized the Hawaiian Islands in the past, and how that rate has changed.

If you have only one class period, reproduce the Teacher Background "Timeline Cards" (pp.49-90). Pass one or more cards out to each student and skip to instruction 4.

- Assign each group several items from the list included in Teacher Background "Timeline Cards" on page 41. This list includes notable dates in Hawaiian natural history from 30 MA to present. (Find more comprehensive lists on pages 44-47: Teacher Background "Tables 1, 2, and 3.")
- 3) For each list item, have students create a card with an image and a few facts, including the date of its initial arrival or occurrence in Hawai'i. Allow them time to research using the library or Internet.

Note: If students' item happens to be an example of adaptive radiation, have them research the original pioneer, note how many species evolved from the pioneer, and include a few images of the descendant species. For example, the introduction of a bellflower 15 million years ago resulted in 125 native Hawaiian species in the lobelia family.

4) Use register tape, flagging tape, or butcher paper to create a timeline from 30 MA (million years ago) to the present. The timeline should include at least three different scales: 30 MA – 5 MA, 5 MA – 0 AD, 0 AD – present. Extra credit: Have students create a logarithm to calculate the dimensions of the scales.

(To emphasize the magnitude of the 30 MA - 5 MA scale, tell students that if one inch represented 100 years, the timeline would stretch out 56 miles.)

- 5) Lead a discussion about plant and animal introductions to Hawai'i, based on Teacher Background "Rate of Introduction Script." As each species or historic event comes up, have students stand and present their cards. If possible, project cards overhead while they are being presented. When finished, have students affix cards in the appropriate spot on the timeline. Introductions go above the timeline; extinctions go below. Ask students questions as you go along to stimulate critical thinking skills.
- 6) Have students complete the Student Pages "Rate of Introduction" (pp. 91-92) worksheet to determine the rate of introduction in different eras of Hawaiian history.
- 7) Use your timeline as the base for an x/y axis graphing the change: time along the x axis and introductions along the y axis. You can use string or flagging tape to indicate rate of change on the classroom timeline, or have students create one of their own on graph paper.



# Journal Ideas\_

- What did you learn about the history of plant introductions in Hawai'i?
- How do you think we as humans can limit the rate of introductions to Hawai'i?
- At what point in the timeline did native species begin to be displaced? At what point were humans negatively impacted?
- Speculate a present outcome if different steps on the timeline were omitted. For example: what if mosquitoes hadn't been introduced?

# Assessment Tools -

- Completed timeline cards
- Participation in class discussion
- "Rate of Introduction" worksheet
- Journal entries

# Further Enrichment –

- Compare the increase in rate of species introductions in Hawai'i to other rate increases. For example, have students theorize what would happen if the rate of house guests increased by ten, twenty, or one thousand-fold in their home.
- Graph the human population on your existing timeline.
- Have students research the records of 18th century ship botanists to see when specific plants were introduced. [See Teacher Background "References for Further Research" (pp. 48).]

# Teacher Background Rate of Introduction Script

(Use this script as a base for discussion as students present their cards. Let students lead with their cards and fill in as necessary.)

The **rate of introduction**, or how often a new species arrives in Hawai'i, has risen dramatically since ancient times. Hawai'i was once one of the world's most isolated locations. A plant, animal, or insect had to overcome substantial obstacles to get to these islands, survive, and reproduce. Successful **colonization** of these islands was rare—just once every few thousand years.

What difference does time make? The first species to **colonize** the Hawaiian Islands existed in **isolation** for many millions of years. Over time, descendents of the first plants and animals **evolved** into new species—species that exist nowhere else on earth. The process of evolution requires both time and **genetic** isolation.

[Note: For more background, see Invasive Species Module Unit 1 Activity #1 "From Isolation to Globalization."]

When humans arrived, everything changed. Everything from a germ to a giraffe could hitch a ride in human cargo. As the modes of travel expanded from canoes to jet airplanes, the number of species arriving—and surviving—in Hawai'i each year skyrocketed.

Today, humans, animals, and plants can now easily circumnavigate the globe. Places that were once very far apart are connected by overnight flights. As an unfortunate consequence, the rich fabric of **ecosystems** that took millions of years to create is being unraveled in a very short time.

During this century, scientists estimate that new plant species arrive at the rate of about five per year—100,000 times more frequently than in the era before humans arrived in Hawai'i.

Let's take a look at some of the major turning points in the history of travel to Hawai'i.

#### Prehistoric period: 30 MA (million years ago) to 500,000 years ago

During the prehistoric period, magma erupts from a **hotspot** on the floor of the Pacific Ocean. Lava pools, forming a giant, undersea mountain that eventually breaks the sea's surface and creates a high, volcanic island. The new island sits on the Pacific **tectonic plate**, which is slowly moving northwest. As the plate shifts, the island is carried away from the stationary hotspot and its active volcanic period ends. A new island forms over the hotspot. Over time, all of these high islands erode, leaving behind coral **atolls**.

During this era, the occasional plant, insect, bird or fish species finds itself a castaway on these islands, carried by strong sea currents or winds. On average, one species per three to five thousand years survives. Among these original pioneers, there are *no* reptiles or amphibians, and just three mammals: the Hawaiian monk seal and two bats (one is now **extinct**). Over **millennia**, the **descendants** of these pioneers evolve into numerous different species through **adaptive radiation**.



By the time the first humans arrive, Hawai'i is home to over 1,000 unique plant species, between 6,000 and 10,000 insect species, 1,200 land snail species, and 115 bird species.

[Note: For more background on adaptive radiation, see the following activities: Invasive Species Module Unit 1 Activity #1 and Rain Forest Module Unit 3 Activities 1-3.]

# ~29.8 million years ago: Kure atoll, the oldest existing landmass in the Hawaiian archipelago, breaks the surface of the ocean as a volcanic island.

After Kure, more islands emerged, one after the next, including Midway, Laysan, Necker (Mokumanamana), and Nihoa. Some of these islands were once nearly as large as the main Hawaiian Islands are today. They were likely populated with unique plant, insect, and bird species that disappeared as the islands themselves vanished into coral atolls. Only a few species from this ancient lineage survived. (These include Hawaiian monk seals, lobelias, *Drosophila* flies, and damselflies.)

#### 26 MA

#### Fruit fly ~ 1000 Drosophila species

Sometime around 26 million years ago, long before the main Hawaiian Islands emerge, a *Drosophila* fly colonizes one of the existing islands. From this single pioneer, over 1,000 species of flies evolved—some known as picture wing flies for their remarkable wing patterns.

#### 15 MA

#### Bellflower ~ 125 lobelia species

The Hawaiian lobelioids are a group of flowering plants in the bellflower family, *Campanulaceae*. This is the largest plant radiation in the Hawaiian Islands, with over 125 species. They all derive from a single introduction, a lobelia-like species that arrived about 15 million years ago. The group includes six genera: *Lobelia*, *Trematolobelia*, *Brighamia*, *Clermontia*, *Cyanea*, and *Delissea*. They are known for their spectacular flowers that evolved in tandem with endemic Hawaiian birds, moths, and flies.

#### 15 MA

#### Hawaiian Monk seal

Known to early Hawaiians as *'ilio holo i ka uaua*, or the "dog that runs in rough waters," the monk seal has been riding the Hawaiian surf for fifteen million years. Deep-sea probe footage recently captured a Hawaiian monk seal foraging at an astonishing 1,770 feet beneath the surface. Marine biologists still have much to learn about this amazing animal.

Question: Why do scientists call the Hawaiian monk seal a "living fossil"?

**Answer:** The species has not changed much in 15 million years, offering scientists a living, breathing example of animals from the past.

#### 9.6 MA

#### Damselfly ~ 23 Megalagrion damselfly species

A pioneer damselfly reached the Hawaiian Islands almost ten million years ago. Its ancestors evolved into twenty-three species. These beautiful acrobatic insects come in all colors: bright red, amber, electric blue. Most of the species have aquatic larval stages. Wingless, gilled juveniles hunt along streambeds for prey.



#### 11 – 5.1 MA Biological Bottleneck

Necker Island, which formed 11 million years ago, was the last large volcano to emerge before the main Hawaiian Islands. During a period of several million years, the Hawaiian archipelago didn't have any tall islands. Several islands formed after Necker and before Ni'ihau, but they were comparatively small, rising no more than 1,000 meters (3,280 feet) above sea level. These islands weren't large enough to support diverse ecosystems in a range of climates. Scientists have referred to this as a bottleneck, since it significantly reduced the **habitats** available to living things. Many species that had been migrating from island to island as each new volcano arose must have gone extinct during this time. Plants, insects, and birds that required the cooler temperatures and heavier rainfall associated with high elevation probably vanished. By the time Ni'ihau finally emerged, it's likely that only a few coastal species survived from the previous 25 million years of evolution.

# 5.1 MA

#### Ni'ihau is formed.

#### 5.1 MA

#### California tarweed ~ 28 species, known as the Silversword Alliance

A small daisy-like weed found its way to Hawai'i more than five million years ago. Its descendants become known as the Silversword Alliance—a group of stunning plants found in some of the harshest climates on Earth. The majestic '*āhinahina*, or silversword, grows at the summit of Haleakalā on Maui, where its silver-haired leaves deflect the intense sun. Its cousin, the greensword, grows in a misty, water-soaked bog at the top of Pu'u Kukui on West Maui.

#### 5-4 MA

#### Eurasian rosefinch ~ 50 Hawaiian honeycreepers

A rather drab finch species is believed to have colonized the Hawaiian Islands between four and five million years ago. From this single **generalist** ancestor, an array of spectacular forest bird species evolves. Each has a **specialized** beak and occupies a unique **niche** in the Hawaiian forest. The Maui parrotbill has a large, heavy beak designed for tearing tree bark to find grubs, while the nectar-sipping 'i'iwi has a long, slender, sickle-shaped bill that fits perfectly into tubular lobelia flowers.

#### 4.7 MA Kauai is formed.

#### 4.2 MA

#### Hawaiian crow

More than four million years ago, crows established themselves in Hawai'i. While only one crow species still exists, fossil remains show that, at one time, there were actually several species. It's not known whether this was the result of multiple introductions or a single introduction that radiated into multiple species. The existing Hawaiian crow, called '*alalā*, is unique among the world's crows. It's mainly a fruit-eater, feeding from '*ie'ie* and '*ōhelo* berries, and spends a greater amount of time in trees than do other crows. The '*alalā* also possesses a remarkable vocal repertoire. Once one of the largest, most charismatic, and culturally significant Hawaiian forest birds, it is now extinct in the wild.



#### Metrosideros

#### 3 – 4 Ma ~ 5 species

Between three and four million years ago, a plant in the myrtle family successfully took root in the Islands. Its descendants evolved into five species, including '*ōhia*, one of the keystone species of the native Hawaiian rain forest. A highly variable species, '*ōhia* grows along the ground as a sprawling shrub or reaches its branches fifty feet high to form a forest canopy. One of the first plants to colonize new lava flows, it is considered sacred to Pele, the Hawaiian volcano goddess.

#### 3.6 MA

#### Moa Nalo ~ 4 species of flightless geese and ducks

Fossils discovered in lava tubes and sinkholes alerted scientists to the existence of several extinct bird species, including large, flightless ducks and geese. These birds most likely evolved from an ancestor belonging to the dabbling duck family. They had huge hind legs, stubby, flightless wings, and beaks like turtles. Since there were no grazing mammals present on the Islands, these unique birds filled that niche.

#### 2.6-3 MA Oʻahu is formed.

#### 2 MA

#### Geranium ~ 7 species

Around two million years ago, a plant in the cranesbill or geranium family arrived in Hawai'i. Over time, its descendants evolved into seven species, remarkable for their unique asymmetrical flower shape, silvery leaves, and tree-like growth habits. They are the world's only woody geraniums. The lovely, red-flowered *Geranium arboreum* is endemic to Maui.

#### 1.2-2.2 MA

*Maui Nui is formed.* The four islands that now make up Maui, Molokai, Lanai, and Kaho'olawe were once joined as a single island. Over time, individual volcanoes eroded and seawater levels rose due to the end of the ice age, creating separate islands.

#### 500,000 years ago-today

#### Hawai'i Island is formed.

The Island of Hawai'i currently sits over the hotspot. (Immediately to its southeast, a new island,  $L\bar{o}$ 'ihi, is forming and has yet to break the surface.)

#### 1000-1250 A.D.: Polynesian voyaging canoes arrive: the first humans to colonize Hawai'i.

#### 1000-1250 A.D.: Polynesians introduce new plants and animals.

During this period (1000-1778 AD) the first people of Hawai'i introduce around 30 plants, three mammals, one bird, and two reptiles. Many of the original pioneer species, including flightless and ground-nesting birds, go extinct during this era. Some of these extinctions result from introduction of the Polynesian rat, which prey on native birds, insects, snails, and plants. The Hawaiians clear extensive areas for agriculture, altering native habitat. They also kill birds for meat and feathers.



Among the 30+ species they introduce: breadfruit, coconut, taro, '*awapuhi* (shampoo ginger), '*ōlena* (tumeric), *mai* '*a* (banana), Polynesian pig, Polynesian rat, dog, chicken, and gecko.

#### 1100-1778: Moa nalo and long-legged flightless owl go extinct.

Predation by rats and humans causes numerous flightless birds go extinct during this period. Flightless birds build their nests on the ground and have no protection from introduced predators.

#### Western colonization

From 1778 to 1882, hundreds of plants are introduced, in addition to numerous animals, insects, and birds. Many more native Hawaiian species go extinct during this period, including forest birds. Free ranging cattle, goats, and pigs decimated native plant populations. The insatiable hunger for sandal-wood to trade with Eastern markets results in the near extinction of the species. In addition, foreign diseases devastate the Native Hawaiians, reducing the population from more than 300,000 people (possibly as many as one million) in 1778 to 54,000 in 1876.

#### 1778: The first Europeans arrive in Hawai'i.

Captain James Cook arrives on the *Endeavour*, and leaves the following behind to outfit his ship on its return: onion, lemon, pumpkin, almond, musk melon, and European boar.

#### 1792: Captain Vancouver

Captain Vancouver brings oranges and gives King Kamehameha several head of cattle. **Question:** what happens to the forest when cattle are turned loose? **Answer:** wild cattle eat and trample native forest plants.

#### 1804: Chinese sandalwood trade begins.

Western fur traders discover dollar signs in the forest: Hawaiian sandalwood, a close relative of the tree revered in the Far East by spiritual devotees. (A dab of sandalwood paste on the forehead was said to open a channel to the divine.) King Kamehameha I trades shiploads of sandalwood logs for Western weapons and boats. Overwhelmed by debt, his successor, Kamehameha II, requires men, women, and children to cut and carry sandalwood from the forest. Farmers are forced to leave their *lo'i* (taro patches), fishermen their fishponds to gather sandalwood. Famine ensues.

#### 1813: Agriculturalist Paul Marin plants pineapple and coffee, among other crops.

#### 1820: Whalers and missionaries begin arriving.

**Question:** What effect would the arrival of whalers have on Hawaiian **flora** and **fauna**? **Answers:** Increased introduction of species associated with whaling ships, such as mosquitoes, rats, and food crops. Spread of diseases such as small pox, syphilis. Diminished population of marine mammals, as whalers harvest these giants of the sea.

#### 1826: Mosquito

Sailors from the whaling ship *Wellington* dump their bilge water, filled with mosquito larvae, into Lahaina canals. Mosquitoes spread disease to humans and birds.



#### 1826-present: Forest birds go extinct.

Many Hawaiian forest birds (eg: ' $\bar{o}$ ' $\bar{o}$ , mamo, 'akialoa) succumb to avian malaria and habitat loss.

# 1839: United States Exploring Expedition

A botanical expedition conducts systematic survey of flora, documenting over 100 species introduced between 1778 and 1839. Among the food plants and weedy species are the following: garlic, cherimoya, soursop, asparagus, turnip, Pride of Barbados, tea, chili pepper, balloon vine, golden beardgrass, watermelon, tangerine, Cucumber, Bermuda grass, angel's trumpet, carrot, sea bean, Brazilian plum, rose apple, fig, cotton, night-blooming cereus, moon flower, morning glory, *koa haole*, macadamia, tobacco, olive, prickly pear cactus, rice, avocado, lima bean, peach, strawberry guava, common guava, pomegranate, common pear, apple, cacao, wheat, grape, corn, and edible ginger.

#### 1840: Sandalwood trade collapses due to over-harvesting.

1840: Sheep arrive in Hawai'i.

Able to scale cliffs, feral sheep access the remaining **pristine** forest areas. They devastate populations of native lobelias, hibiscus, and other rare plants.

#### 1860: Sugar industry

As whaling declines, the sugar industry thrives; workers from China and Japan are brought in to work the fields.

**Question:** How might the arrival of plantation workers from Asia affect introductions? **Answer:** Increase in species from Asia, such as food plants, songbirds, and work animals.

# 1870: Eucalyptus widely planted on Maui.

# 1882: Matson Lines begins overseas shipping operations.

# 1890: Nēnē, the Hawaiian goose, disappears from Maui.

Introduced cats, rats, and mongeese prey on the ground-nesting bird's eggs and chicks. Habitat destruction also plays a role in the goose's near extinction.

# 1910: Mediterranean fruit fly arrives in Hawai'i.

**Question:** What effect would an exotic fruit fly have on Hawaiian flora and fauna? **Answer:** Could compete with the native *Drosophila* flies. Damages agricultural industry, since infested fruits cannot be exported.

# 1936: The first commercial flights to Hawai'i begin.

**Question:** What effect would jet travel have on Hawaiian flora and fauna? **Answer:** Increased introduction of exotic species from around the globe, including short-lived organisms and diseases that might not have survived long boat rides.

# 1962: Nēnē re-introduced into Haleakalā National Park.

A captive breeding program in England successfully raises  $n\bar{e}n\bar{e}$  goslings, which are brought home to Maui and released in Haleakalā National Park with the help of the Boy Scouts.

#### 1976: Fencing of Haleakalā National Park boundary begins.

Fencing designed to exclude feral goats and deer protects the rare plants, birds, and insects that dwell with in the park. This work continues today.

Question: How does this affect introductions into the park?

**Answer:** Native Hawaiian species are protected from grazing mammals and predators. They are able to flourish.

#### 1991: The Melastome Action Committee forms.

Conservationists from several agencies band together to stop the invasion of highly aggressive plants in the melastome family, including *Miconia calvescens*. Ultimately this results in the creation of the Invasive Species Committees on each island, tasked with preventing the introduction and spread of harmful alien species.

Question: How does the creation of these agencies affect introductions?

**Answer:** Field crews are able to stop new **invasions** and contain existing populations of invasive species.

# 1994: Honolulu ranked as fifteenth busiest airport in the U.S., handling 22.9 million passengers per year.

#### 2009: Po'ouli goes extinct.

Discovered in 1973, the *po'ouli* goes extinct. Despite dedicated efforts by conservation agencies to find reproductive birds, the last known individual dies in captivity. The causes of its extinction: habitat loss, avian malaria, and decline in the bird's primary food source, native Hawaiian tree snails.

Ongoing: Conservation agencies work to preserve intact native Hawaiian ecosystems and prevent the introduction of new species. (Agencies include: Haleakalā National Park, The Nature Conservancy, Sierra Club, Hawaiian Islands Land Trust, Maui Invasive Species Committee, East Maui Watershed Partnership, West Maui Mountains Watershed Partnership, Leeward Haleakalā Watershed Partnership, Lanai Forest & Watershed Partnership, East Molokai Watershed Partnership, among others.)

*Today:* ~ 5 plants and 20-40 new insects successfully **naturalize** in the Hawaiian Islands per year.

From 1839 to 2011 over 5,000 plant and animal species colonized Hawai'i. Many more were introduced but did not survive. During the first half of the twentieth century, species from around the world got a free ticket to Hawai'i. Some were brought intentionally, others by accident. Some became aggressive invaders, dominating resources and contributing to the decline of native Hawaiian ecosystems and their associated species.

State and Federal laws have been enacted to protect native Hawaiian species, but the fiftieth state has already earned the title of "extinction capital" of the United States.



# es Unit 1

# Teacher Background **Timeline Cards**

Assign a student or group of students one or more of the items on this list to research. Tell them to create cards with an image and 3-5 sentences about their subject, including the date of its arrival or occurrence in Hawai'i.

The items with asterisks are single introductions that evolved into numerous species, as a result of adaptive radiation. The original pioneer species is listed along with the native Hawaiian radiation in parentheses. Ask students to document how many species resulted from the radiation and give a few examples. For example, the introduction of a bellflower 15 million years ago resulted in ~125 native Hawaiian species in the lobelia family. The California tarweed's ancestors radiated into ~ 28 species known as the Silversword Alliance. These include the silversword, greensword, and  $k\bar{u}pa$  'oa.

- 1. Kure Atoll
- 2. Fruit fly (Hawaiian Drosophila flies) \*
- 3. Bellflower (Hawaiian lobelioids) \*
- 4. Hawaiian monk seal
- Damselfly (Hawaiian Megalagrion damselflies) \*
- 6. Biological Bottleneck
- 7. Ni'ihau
- 8. Eurasian rosefinch (Hawaiian honeycreepers) \*
- 9. California tarweed (Silversword alliance) \*
- 10. Kaua'i
- 11. Hawaiian crow
- 12. Metrosideros ('ōhia species.) \*
- 13. Moa nalo (flightless ducks and geese)\*
- 14. Oʻahu
- 15. Geranium (Hawaiian geraniums) \*
- 16. Maui Nui
- 17. Hawai'i Island
- 18. Polynesian voyaging canoes
- 19. Polynesian introductions
- 20. *Moa nalo* and other flightless birds go extinct
- 21. Western colonization begins with the arrival of the Europeans. Captain Cook arrives on the *Endeavor* (what did he bring?)
- 22. Captain Vancouver (what did he bring?)
- 23. Chinese sandalwood trade begins
- 24. Paul Marin (what did he bring?)

- 25. Whalers and missionaries arrive
- 26. Mosquito
- 27. Many Hawaiian forest birds go extinct (eg: 'ō'ō, mamo, 'akialoa)
- 28. U.S. Exploring Expedition
- 29. Sandalwood trade collapses
- 30. Sheep
- 31. Sugar industry
- 32. Eucalyptus
- 33. Matson Lines shipping begins
- 34. *Nēnē*, the Hawaiian goose, disappears from Maui
- 35. Mediterranean fruit fly
- 36. The first commercial flights to Hawai'i begin
- 37. *Nēnē* re-introduced into Haleakalā National Park
- 38. Fencing of Haleakalā National Park boundary begins.
- 39. The Melastome Action Committee forms
- 40. Honolulu ranks as fifteenth busiest airport in U.S.
- 41. The po'ouli goes extinct
- 42. Ongoing: conservation agencies work to preserve Hawaiian ecosystems

# Teacher Version Rate of Introduction

Use the information below to graph the rate of successful colonization by plant, insect, and bird species in the Hawaiian Islands. Using the graph on the next page, plot time on the X axis and introductions on the Y axis. To do so, you must first determine how many species were introduced per year for each of the time segments.

Use this worksheet to determine the rate.

During the prehistoric period, an average of one plant, bird, or insect species successfully colonized the islands every few thousand years. 1 species/3000 years.

Between 5.1 Ma and 1000 AD\_0.00333 species were introduced per year.

During 1000-1778 AD, the first people of Hawai'i introduced around 30 plants, three mammals, one bird, two reptiles. 36 species/778 years

From 1000-1778 AD 0.046272 species were introduced per year.

From 1778 to 1840 around one hundred plants were introduced, in addition to numerous animals, insects, and birds. ~100 species/60 years

From 1778-1840 AD 1.66667 species were introduced per year.

Today <u>5 plant and 20-40 new insect</u> species are introduced per year.





Rate of Species Introduction in Hawaii

#### Extra Credit

Graph the changes in the human population of Hawai'i.

Prior to 1000 AD, the population was zero.

In 1778 AD, the estimated population was between 300,000 and one million.

In 1886 AD, the estimated population was <u>54,000</u>.

Today, the population is <u>1,374,810</u> (in 2012).

U

# Teacher Background Further Enrichment

The following tables provide extra resources for you to draw from, if you would like to expand the number of items listed on your timeline.

# Table 1. Pioneer Species

The table charts the arrival of ancestral pioneer species over 29 million years. The first column lists the name of the ancestral species or genera. The second column records the number of species that evolved from the original ancestor. The third column represents when the pioneer species arrived in Hawai'i, in millions of years. (Price & Clague 2002)

Lineage	Number of Species	Age (Ma)
Hawaiian fruitflies (Drosophilidae)	ca. 1000	26
Hawaiian monk seal (Monachus schauinslandi)	1	15
Hawaiian lobelioids (Campanulaceae)	125	15
Megalagrion damselflies (Coenagrionidae)	23	9.6
Silversword alliance (Asteraceae)	28	5.1
Laysan duck (Anas laysanensis, Anatidae)	1	<5
Hawaiian crow (Corvus Hawaiiensis, Corvidae)	1 (?)	4.2
Hawaiian honeycreepers (Drepanidinae, Fringillidae)	ca. 50	4-5
Metrosideros spp. (Myrtaceae)	5	3-4
Viola spp (Violaceae)	6	3.7
Moa nalo, flightless Anseriformes (Anatidae)	4	3.6
Hawaiian thrushes (Myadestes spp., Muscicapidae)	5	3.35
Kokia spp. (Malvaceae)	4	3
Flightless rails (Porzana sandwicensis, Rallidae)	1	2.95
Geranium spp. (Geraniaceae)	7	2
Hesperomannia spp. (Asteraceae)	4	1.81-4.91
Flightless ibises (Apteribis spp., Plataleidae)	2	1.6
Hawaiian duck (Anas wyvilliana, Anatidae)	1	1.5
Hawaiian geese (Branta spp., Anatidae)	3	1
Hawaiian black-necked stilt (Himantous mexicanus knud-	1	0.75
senii, Recurvirostridae)		
Hawaiian hawk (Buteo solitarius, Accipitridae)	1	.07
Tetramolopium spp. (Asteraceae)	11	0.6-0.7



# Table 2. Polynesian Introductions

The following is a list of plants introduced by Polynesian voyagers, according to renowned botanist Dr. Harold St. John.

÷

English	Hawaiian	Latin
Kukui	Kukui	Aleurites moluccana
	'Ape	Alocasia macrorrhiza
Breadfruit	Ulu	Artocarpus altilis
	Wauke	Broussonetia papyrifera
	Kamani	Calophyllum inophyllum
Coconut	Niu	Cocos nucifera
Taro	Kalo	Colocasia esculenta
	Кои	Cordia subcordata
	Ti	Cordyline terminalis
	'Ōlena	Curcuma longa
	Kūkaepua'a	Digitaria pruriens
Yam	Uhi	Dioscorea alata
	Pi'oi	Dioscorea bulbifera
	<i>Pi</i> 'ia	Dioscorea pentaphylla
Mountain apple	ʻōhi'a ai	Eugenia malaccensis
Indigo		Indigofera suffruticosa
	Kāmole	Ludwigia octivalvis
Hairy merremia		Merremia aefiyptia
	Noni	Morinda citrifolia
Banana	Mai'a	Musa spp.
	Pāʻihi	Nasturtium sarmentosum
Yellow wood sorrel		Oxalis corniculata
	'Awa	Piper methysticum
Sugarcane	Kō	Saccharum officinarum
Bamboo	'Ohe	Schizostachyum glaucifolium
	Pia	Tacca leontopetaloides
	ʻAhuhu	Tephrosia purpurea
	Milo	Thespesia populnea
Aramina		Urena lobata
	'Awapuhi	Zingiber zerumbet

The Polynesians also introduced animals:

Polynesian pig, Polynesian rat, dog, chicken, skink, gecko

6

Table 3. Species recorded by the 1839 U.S. Botanical Expedition

The following species were introduced to Hawai'i sometime between 1778 and 1839. [This is a partial list, drawn from "Early Plant Introductions in Hawai'i" by Kenneth Nagata, The Hawaiian Journal of History, vol. 19 (1985).]

Garlic	Allium sativum		
Pineapple	Ananas comosus		
Cherimoya	Annona cherimola		
Soursop	Annona muricata		
Asparagus	Asparagus officinalis		
Arnotto	Bixa orellana		
Wild Mustard	Brassica campestris		
Turnip	Brassica rapa var. rapa		
Pride of Barbados	Caesalpinia pulcherrima		
Pigeon pea	Cajanus cajan		
Tea	Camellia sinensis		
Common Canna	Canna indica		
Chili pepper	Capsicum annuum		
Balloon vine	Cardiospermum halicacabum		
Golden beardgrass	Chrysopogon aciculatus		
Watermelon	Citrullus lanatus		
Tangerine	Citrus reticulata		
Spider flower	Cleome spinosa		
Calabash tree	Crescentia cujete		
Cucumber	Cucumis sativus		
Bermuda grass	Cynodon dactylon var. dactylon		
Makaloa	Cyperus laevigatus		
Angel's trumpet	Datura arborea		
Carrot	Daucus carota		
Sea bean	Dioclea wilsonii		
Dragon tree	Dracaena draco		
Goosegrass	Eleusine indica		
Horseweed	Erigeron canadensis		
Water apple	Eugenia aquea		
Brazilian plum	Eugenia dombeyi		
Rose apple	Sygygium jambos		
Garden spurge	Euphorbia hirta		
Longan	Euphoria longana		
Fig	Ficus carica		
Cotton	Gossypium sp.		
Whorled marsh pennywort	Hydrocotyle verticillata		
Night-blooming cereus	Hylocereus undatus		
Moon flower	Ipomea alba		



# Table 3, continued...

Morning glory *Ipomea purpurea* English walnut Juglans regia Lettuce Lactuca sativa Wild peppergrass Lepidium virginicum Koa haole Leucaena leucocephala Macadamia Macademia ternifolia var. integrifolia Small-flowered mallow Malva parviflora Chinaberry Melia azedarach Tobacco Nicotiana tabacum Olive Olea europaea Basketgrass **Oplismenus hirtellus** Prickly pear cactus Opuntia megacantha Rice Oryza sativa Avocado Persea americana Parsley *Petroselinum crispum* Phaseolus limensis Lima bean Common bean Phaseolus vulgaris Pea Pisum sativum Spurflower Plectranthus parviflorus Pondweed Potamogeton sp. Common purslane *Portulaca oleracea* Prosopis pallida Kiawe Apricot Prunus armenica Almond Prunus dulcis Peach Prunus persica Strawberry guava Psidium cattleianum Common guava Psidium guajava Pomegranate Punica granatum Common pear Pyrus communis Apple Pyrus malus Caster bean Ricinus communis Damask rose Rosa damascena Cuba jute Sida rhombifolia Eggplant Solanum melongena Potato Solanum tuberosum Tamarind Tamarindus indica Cacao Theobroma cacao Wheat Triticum aestivum Grape Vitis vinifera Corn Zea mays Edible ginger Zingiber officinale

# Teacher Background References for Further Research

#### Polynesian introductions

Cuddihy and Stone, Alteration of Native Hawaiian Vegetation, University of Hawaii Press, 1990.

Ziegler, Hawaiian Natural History, Ecology, and Evolution, University of Hawaii Press, 2002.

# 18th and 19th century western introductions

Nagata, Kenneth, "Early Plant Introductions in Hawai'i," *The Hawaiian Journal of History, Hawaiian History Society*, vol. 19, 1985.

State Department of Agriculture website: http://hawaii.gov/hdoa/ag-resources/history

#### Ship naturalists and botanists

James Cook 1778-79 Nelson 1779 La Perouse 1786 Meares 1788-89 Menzies 1792-94 Gaudichaud 1819

Bloxam, Richard, Byron, George, and Calcott, Maria, *Voyage of H.M.S. Blonde to the Sandwich Islands, in the years 1824-1825.* John Murray, London, 1826, p. 86.

#### Human population

Juvik, Sonia P. and Juvik, James O., *Atlas of Hawai'i*, Thomas R. Paradise, University of Hawai'i Press, October 1998.

U.S. Census www.census.gov/population

Nordyke and Matsumoto, "The Japanese in Hawai'i: a historical and demographic perspective," *The Hawaiian Journal of History*, Hawaiian History Society, vol. 11, 1977.









#### ~29.8 million years ago:

Kure atoll, the oldest existing landmass in the Hawaiian archipelago, breaks the surface of the ocean as a volcanic island.

#### 26 million years ago:

Fruit fly ~ 1000 Drosophila species

Sometime around 26 million years ago, long before the main Hawaiian Islands emerge, a *Drosophila* fly colonizes one of the existing islands. From this single pioneer, over 1,000 species of flies evolved—some known as picture wing flies for their remarkable wing patterns.









#### 15 million years ago

Bellflower ~ 125 lobelia species

The Hawaiian lobelioids are a group of flowering plants in the bellflower family, *Campanulaceae*. This is the largest plant radiation in the Hawaiian Islands, with over 125 species. They all derive from a single introduction, a lobelia-like species that arrived about 15 million years ago. The group includes six genera: *Lobelia*, *Trematolobelia*, *Brighamia*, *Clermontia*, *Cyanea*, and *Delissea*. They are known for their spectacular flowers that evolved in tandem with endemic Hawaiian birds, moths, and flies.

#### 15 million years ago Hawaiian Monk seal

Known to early Hawaiians as *`īlio holo i ka uaua*, or the "dog that runs in rough waters," the monk seal has been riding the Hawaiian surf for fifteen million years. Deep-sea probe footage recently captured a Hawaiian monk seal foraging at an astonishing 1,770 feet beneath the surface. Marine biologists still have much to learn about this amazing animal.











#### 11 – 5.1 MA Biological Bottleneck

Necker Island, which formed 11 million years ago, was the last large volcano to emerge before the main Hawaiian Islands. During a period of several million years, the Hawaiian archipelago didn't have any tall islands. Several islands formed after Necker and before Ni'ihau, but they were comparatively small, rising no more than 1,000 meters (3,280 feet) above sea level. These islands weren't large enough to support diverse ecosystems in a range of climates. Scientists have referred to this as a bottleneck, since it significantly reduced the **habitats** available to living things. Many species that had been migrating from island to island as each new volcano arose must have gone extinct during this time. Plants, insects, and birds that required the cooler temperatures and heavier rainfall associated with high elevation probably vanished. By the time Ni'ihau finally emerged, it's likely that only a few coastal species survived from the previous 25 million years of evolution.









# 5.1 million years ago Ni'ihau is formed.

#### 5.1 million years ago

*California tarweed* ~ 28 species, known as the Silversword Alliance A small daisy-like weed found its way to Hawai'i more than five million years ago. Its descendants become known as the Silversword Alliance—a group of stunning plants found in some of the harshest climates on Earth. The majestic '*āhinahina*, or silversword, grows at the summit of Haleakalā on Maui, where its silver-haired leaves deflect the intense sun. Its cousin, the greensword, grows in a misty, water-soaked bog at the top of Pu'u Kukui on West Maui.









#### 5-4 million years ago

*Eurasian rosefinch* ~ 50 Hawaiian honeycreepers A rather drab finch species is believed to have colonized the Hawaiian Islands between four and five million years ago. From this single **generalist** ancestor, an array of spectacular forest bird species evolves. Each has a **specialized** beak and occupies a unique **niche** in the Hawaiian forest. The Maui parrotbill has a large, heavy beak designed for tearing tree bark to find grubs, while the nectar-sipping *'i'iwi* has a long, slender, sickle-shaped bill that fits perfectly into tubular lobelia flowers.

4.7 million years ago *Kaua'i is formed*.











#### 4.2 million years ago Hawaiian crow

More than four million years ago, crows established themselves in Hawai'i. While only one crow species still exists, fossil remains show that, at one time, there were actually several species. The existing Hawaiian crow, called '*alalā*, is unique among the world's crows. It's mainly a fruit-eater, feeding from '*ie*'*ie* and '*ōhelo* berries. The '*alalā* also possesses a remarkable vocal repertoire. Once one of the largest, most charismatic, and culturally significant Hawaiian forest birds, it is now extinct in the wild.

# 3-4 million years ago

*Metrosideros* - 5 species Between three and four million years ago, a plant in the myrtle family successfully took root in the Islands. Its descendants evolved into five species, including 'ōhia, one of the keystone species of the native Hawaiian rain forest. A highly variable species, 'ōhia grows along the ground as a sprawling shrub or reaches its branches fifty feet high to form a forest canopy. One of the first plants to colonize new lava flows, it is considered sacred to Pele, the Hawaiian volcano goddess.

#### 3.6 million years ago

Moa nalu ~ 4 species of flightless geese and ducks Fossils discovered in lava tubes and sinkholes alerted scientists to the existence of several extinct bird species, including large, flightless ducks and geese. These birds most likely evolved from an ancestor belonging to the dabbling duck family. They had huge hind legs, stubby, flightless wings, and beaks like turtles. Since there were no grazing mammals present on the Islands, these unique birds filled that niche.








#### 2.6-3 million years ago O'ahu is formed.

# 2 million years ago

*Geranium* ~ 7 species Around two million years ago, a plant in the cranesbill or geranium family arrived in Hawai'i. Over time, its descendants evolved into seven species, remarkable for their unique asymmetrical flower shape, silvery leaves, and tree-like growth habits. They are the world's only woody geraniums. The lovely, red-flowered *Geranium arboreum* is endemic to Maui.









## 1.2-2.2 million years ago Maui Nui is formed.

The four islands that now make up Maui, Molokai, Lanai, and Kaho'olawe were once joined as a single island. Over time, individual volcanoes eroded and seawater levels rose due to the end of the ice age, creating separate islands.

#### 500,000 years ago-today Hawai'i Island is formed.

The Island of Hawai'i currently sits over the hotspot. (Immediately to its southeast, a new island, Lō'ihi, is forming and has yet to break the surface.)















#### 1000-1250 A.D.

#### Polynesians introduce new plants and animals.

During this period (1000-1778 AD) the first people of Hawai'i introduce around 30 plants, three mammals, one bird, and two reptiles. Many of the original pioneer species, including flightless and ground-nesting birds, go extinct during this era. Some of these extinctions result from introduction of the Polynesian rat, which preys on native birds, insects, snails, and plants. The Hawaiians clear extensive areas for agriculture, altering native habitat. They also kill birds for meat and feathers. Among the 30+ species they introduce: *ulu* (breadfruit), *niu* (coconut), *kalo* (taro), '*awapuhi* (shampoo ginger), '*ōlena* (tumeric), *mai*'a (banana), *pua*'a (Polynesian pig), '*iole* (Polynesian rat), '*īlio* (dog), *moa* (chicken), and *mo*'o (gecko).







## 1100-1778 Moa nalo and long-legged flightless owl go extinct.

Predation by rats and humans causes numerous flightless birds go extinct during this period. Flightless birds build their nests on the ground and have no protection from introduced predators.

#### Western colonization

From 1778 to 1882, hundreds of plants are introduced, in addition to numerous animals, insects, and birds. Many more native Hawaiian species go extinct during this period, including forest birds. Free ranging cattle, goats, and pigs decimated native plant populations. The insatiable hunger for sandalwood to trade with Eastern markets results in the near extinction of the species. In addition, foreign diseases devastate the Native Hawaiians, reducing the population from more than 300,000 people (possibly as many as one million) in 1778 to 54,000 in 1876.

















#### Chinese sandalwood trade begins.

Western fur traders discover dollar signs in the forest: Hawaiian sandalwood, a close relative of the tree revered in the Far East by spiritual devotees. (A dab of sandalwood paste on the forehead was said to open a channel to the divine.) King Kamehameha I trades shiploads of sandalwood logs for Western weapons and boats. Overwhelmed by debt, his successor, Kamehameha II, requires men, women, and children to cut and carry sandalwood from the forest. Farmers are forced to leave their *lo i* (taro patches), fishermen their fishponds to gather sandalwood. Famine ensues.

#### 1813

Agriculturalist Paul Marin plants pineapple and coffee, among other crops.

Invasive Species Unit 1 Copy Master









and birds.





#### United States Exploring Expedition

A botanical expedition conducts systematic survey of flora, documenting over 100 species introduced between 1778 and 1839. Among the food plants and weedy species are the following: garlic, cherimoya, soursop, asparagus, turnip, Pride of Barbados, tea, chili pepper, balloon vine, golden beardgrass, watermelon, tangerine, Cucumber, Bermuda grass, angel's trumpet, carrot, sea bean, Brazilian plum, rose apple, fig, cotton, night-blooming cereus, moon flower, morning glory, *koa haole*, macadamia, tobacco, olive, prickly pear cactus, rice, avocado, lima bean, peach, strawberry guava, common guava, pomegranate, common pear, apple, cacao, wheat, grape, corn, and edible ginger.









1840 Sandalwood trade collapses due to over-harvesting.

#### 1840

Sheep arrive in Hawai'i. Able to scale cliffs, feral sheep access the remaining **pristine** forest areas. They devastate populations of native lobelias, hibiscus, and other rare plants.









Eucalyptus widely planted on Maui. 1870 workers from China and Japan are brought in to As whaling declines, the sugar industry thrives; work the fields. Sugar industry 1860





1882 Matson Lines begins overseas shipping operations.

# 1890

Nēnē, the Hawaiian goose, disappears from Maui.
Introduced cats, rats, and mongeese prey on the ground-nesting bird's eggs and chicks. Habitat destruction also plays a role in the goose's near extinction.

**1910** Mediterranean fruit fly arrives in Hawai'i.









**1936** The first commercial flights to Hawai'i begin.

# 1962

 $N\bar{e}n\bar{e}$  re-introduced into Haleakalā National Park. A captive breeding program in England successfully raises  $n\bar{e}n\bar{e}$  goslings, which are brought home to Maui and released in Haleakalā National Park with the help of the Boy Scouts.







#### Fencing of Haleakalā National Park boundary begins.

Fencing designed to exclude feral goats and deer protects the rare plants, birds, and insects that dwell with in the park. This work continues today.

#### 1991

#### The Melastome Action Committee forms.

Conservationists from several agencies band together to stop the invasion of highly aggressive plants in the melastome family, including *Miconia calvescens*. Ultimately this results in the creation of the Invasive Species Committees on each island, tasked with preventing the introduction and spread of harmful alien species.

#### 1994

Honolulu ranked as fifteenth busiest airport in the U.S., handling 22.9 million passengers per year.









#### Po'ouli goes extinct.

Discovered in 1973, the *po ouli* goes extinct. Despite dedicated efforts by conservation agencies to find reproductive birds, the last known individual dies in captivity. The causes of its extinction: habitat loss, avian malaria, and decline in the bird's primary food source, native Hawaiian tree snails.

#### Ongoing

Conservation agencies work to preserve intact native Hawaiian ecosystems and prevent the introduction of new species. (Agencies include: Haleakalā National Park, The Nature Conservancy, Sierra Club, Hawaiian Islands Land Trust, Maui Invasive Species Committee, East Maui Watershed Partnership, West Maui Mountains Watershed Partnership, Leeward Haleakalā Watershed Partnership, Lanai Forest & Watershed Partnership, East Molokai Watershed Partnership, among others.)

# Rate of Introduction

Use the information below to graph the rate of successful colonization by plant, insect, and bird species in the Hawaiian Islands. Using the graph on the next page, plot time on the X axis and introductions on the Y axis. To do so, you must first determine how many species were introduced per year for each of the time segments.

Use this worksheet to determine the rate.

During the prehistoric period, an average of one plant, bird, or insect species successfully colonized the islands every few thousand years. 1 species / 3000 years.

Between 30 Ma and 1000 AD \_\_\_\_\_\_ species were introduced per year.

During 1000-1778 AD, the first people of Hawai'i introduced around 30 plants, three mammals, one bird, two reptiles. 36 species/778 years.

From 1000-1778 AD \_\_\_\_\_\_\_ species were introduced per year.

From 1778 to 1840 around one hundred plants were introduced, in addition to numerous animals, insects, and birds. ~100 species/60 years.

From 1778-1840 AD\_\_\_\_\_\_ species were introduced per year.

Today\_\_\_\_\_\_ species are introduced per year.



Activity #4 Invasive Species Unit 1



# Activity #4

# Where Did They Come From? Where Can They Invade?

#### Length:

One class period

# **Prerequisite Activity:** None

#### **Objectives:**

- Map the origins of invasive species and indicate possible pathways to Hawai'i.
- Map which areas on Maui specific invasive species are likely to invade based on climate, elevation, and other factors.

Note: Students will produce species cards that can be used as resources for Unit 1 Act #5 "Invasive Species Jeopardy."

#### Vocabulary

Alpine Aeolian Coastal Dispersal Dryland forest Marine Mesic Forest Rain forest Vector

# • • • Class Period One: Learning About Names

#### Materials & Setup-

Note: Exercises require access to research materials, Internet, or library. Data and maps for Moloka'i, Lāna'i and Koho'olawe is also provided.

"Maui Hillshade," "Maui Elevation," and "Maui Rainfall" (acetates) (pp. 103-105)

For each group of students:

- "Maui Hillshade," "Maui Elevation," and "Maui Rainfall" (color copies) (pp. 103-105)
- Species flyers (pp. 117-126)

For each student

- Student Page "Exercise 1: Where Did They Come From?" (p. 127)
- Student Page "Exercise 2: Where Can They Invade?" (pp. 128-131)

# Instructions

1) Tell students that they will be investigating where invasive species originally come from and what



Activity #4 Invasive Species Unit 1

habitats they can invade once they get to Maui. Students can work individually or in groups.

2) Assign students one or more of the species listed in Teacher Background "Exercise 1: Where Did They Come From?" Allow them access to library materials, the Internet, and flyers circulated by various natural resource agencies, such as the Hawai'i Department of Agriculture, Hawai'i Department of Land and Natural Resources, and Maui Invasive Species Committee.

Note: If you want to simplify this activity, assign only the seven species highlighted on "Exercise 1: Where Did They Come From?" Flyers describing these species are included in the student pages.

- 3) Tell students to find the natural ranges of the assigned species, based on elevation and rainfall. Have them illustrate each species on a card, list its scientific and common names, where it came from, its preferred climate, and elevation. (These cards are used to play a game: Invasive Species Module Unit 1 Act #5 "Invasive Species Jeopardy.")
- 4) Assign Student Page "Exercise 1: Where Did They Come From?"(p. 127) Discuss the answers in class.
- 5) Assign Student Pages "Exercise 2: Where Can They Invade?" (pp. 128-131)
- 6) Allow students time to complete their cards. Project Acetate Masters "Maui Hillshade" "Maui Elevation" and "Maui Rainfall" on a chalk or dry erase board. Indicate which side of each island is leeward and which is windward. Have students read the descriptions of each ecosystem aloud.
- 7) When students have completed their cards, let them present their species to the class, and then affix the cards to the appropriate place on the map of Maui.
- 8) Discuss how Maui might change if these species were to dominate the ecosystems they are capable of invading. Remind students that what happens at the top of the mountain continues all the way down, affecting each of the lower ecosystems. For instance, a miconia invasion in the rain forest increases erosion, which could smother coral reefs in sediment.
- 9) To expand this lesson, you can discuss the origin of native Hawaiian species. See Teacher Background "What About the Natives?" (p. 102)

# Journal Ideas-

- What factors make Hawai'i especially vulnerable to introduced species?
- What characteristics might make a species more likely to survive in a new environment?
- Why did people bring the invasive species mentioned in this lesson to Hawai'i? If you don't know, formulate some reasonable guesses.

# Assessment Tools-

• Participation in class discussion


- Completed worksheets
- Journal entries

# Further Enrichment

• Two maps included in the teacher background show major vegetation types before and after human contact. Use these maps as a springboard for discussion about how human activity has altered the Hawaiian ecosystems. What native Hawaiian plants grew in each vegetation type? What grows there now? Which vegetation types have been the most altered by human contact? Why?



The following is a list of invasive species that have been found on Maui. Assign between one and five of these species to each student or group of students.

Note: Flyers that contain all of the information needed for this lesson are included for the species listed in **bold**. The other species will need to be researched, using library materials, the Internet, and flyers circulated by various natural resource agencies, such as the Hawai'i Department of Agriculture, Hawai'i Department of Land and Natural Resources, and Maui Invasive Species Committee.

African tulip (*Spathodea campanulata*) Argentine ant (Linepithema humile) Axis deer (Axis axis) Banana poka (Passiflora tarminiana) Boar (Sus scrofa) Bocconia, or plume poppy (Bocconia frutescens) Clidemia (*Clidemia hirta*) Coqui frog (*Eleutherodactylus coqui*) False 'awa (*Piper auritum*) Fountain grass (Cenchrus setaceus) Giant reed (Arundo donax) Goat (*Capra hircus*) Gorilla ogo (*Gracilaria salicornia*) Ironwood (*Casuarina equisetifolia*) Ivy gourd (*Coccinia grandis*) Kahili ginger (Hedychium gardnerianum) Kikuyu grass (*Pennisetum clandestinum*) Mexican creeper (Antigonon leptopus) Miconia (Miconia calvescens) Mosquito (*Culex quinquefasciatus*) Mullein (Verbascum thapsus) Pampas grass (Cortaderia jubata, Cortaderia selloana) Polynesian rat (Rattus exulans) Rat (Rattus rattus) Red hook seaweed (*Hypnea musciformis*) Roi (*Cephalopholis argus*) **Rubber vine** (*Cryptostegia grandiflora*) Strawberry guava (Psidium cattleianum) Veiled chameleon (*Chamaeleo calyptratus*) Yellow Himalayan raspberry (*Rubus ellipticus*) Yellow jacket (Vespula pensylvanica)

Activity #4 Invasive Species Unit 1



# Answer Key Exercise 1: Where Did They Come From?

Below you'll find a list of invasive species that are now found in Hawai'i. Where did they come from? Do some research to find out. Map their origins below. Draw a line from each plant or animal's place of origin and suggest a possible **vector**, or means of **dispersal**. For instance, do you think miconia seeds blew here on the wind or did someone bring a live plant over on the plane? Create a legend to indicate the various vectors.

Puerto Rico
North Africa
Tropical Africa and Asia
Mexico, Central/South America
South America
Madagascar
Yemen, Saudi Arabia



Activity #4 Invasive Species Unit 1

Teacher Version Exercise 2: Where Can They Invade? Sample Card



Common Name: <u>Veiled chameleon</u> Scientific name: <u>Chamaeleo calyptratus</u> Description: <u>Lizard with shark-fin-like bony shield</u> on head; long, thin legs; fleshy fringe running down belly from under its nose to the base of its tail. Up to two feet in length. Origin: <u>Yemen, Saudi Arabia</u> Preferred climate type: <u>wide range</u> Rainfall: <u>wide range</u> Elevation: <u>sea level to 10,000 feet</u> Impacts in Hawai'i: <u>can prey on native plants, birds</u> and insects. Ecosystems this species can invade in Hawai'i: <u>alpine</u> <u>aeolian, mesic forest, rain forest, dryland forest,</u> and coastal

Activity #4 Invasive Species Unit 1



# Answer Key Exercise 2: Where Can They Invade?

Once a plant or animal species arrives on our shores, it has to settle in suitable habitat in order to survive. It needs the right amount of rain, sunlight and heat, in addition to the adequate food, mates, and/ or pollinators. Below are descriptions of ecosystems found on Maui. Which one(s) can your species invade?

## **Alpine Aeolian**

This high-altitude region of Maui is characterized by sparse vegetation and an extreme climate with widely varying daily temperatures, intense solar radiation, and an average of 30-50 inches of rain per year. Few plants thrive here: the spectacular Haleakalā silversword (*Argyroxiphium sandwicense* subsp. *macrocephalum*), 'ōhelo (Vaccinium reticulatum), hinahina (Artemisia australis), and kūpa 'oa (*Dubautia ciliolata*). This describes the summit of Haleakalā, above 7,500 feet.

Species that can invade this ecosystem include:

Argentine ant (*Linepithema humile*) Fountain grass (*Pennisetum setaceum*) Goat (*Capra hircus*) Mullein (*Verbascum thapsus*) Pampas grass (*Cortaderia jubata, Cortaderia selloana*) Polynesian rat (*Rattus exulans*) Black rat (*Rattus rattus*) Veiled chameleon (*Chamaeleo calyptratus*) Yellow jacket (*Vespula pensylvanica*)

## **Mesic Forest**

Mesic forests occur on both East and West Maui, mostly between 2,500-4,100 feet elevation, with between 40 to100 inches of rain per year. Before human contact, this was probably the most botanically diverse of all Hawaiian forests. *Koa* (*Acacia koa*), 'ōhi'a (*Metrosideros polymorpha*), and sandalwood (*Santalum haleakalae*) trees are common, in addition to a mixture of plants adapted to both wet and dry areas such as *maile* (*Alyxia stellata*) and *halapepe* (*Pleomele auwahiensis*). Good examples can be found in East Kaupo gap, Kahikinui, upper Auwahi and 'Ulupalakua, Polipoli, and Makawao Forest Reserve.

Species that can invade this ecosystem include:
Banana poka (*Passiflora mollissima*)
Boar (*Sus scrofa*)
Bocconia, or Plume poppy (*Bocconia frutescens*)
Kikuyu grass (*Pennisetum clandestinum*)
Pampas grass (*Cortaderia jubata, Cortaderia selloana*)
Polynesian rat (*Rattus exulans*)
Mosquito (*Culex quinquefasciatus*)
Black rat (*Rattus rattus*)
Strawberry guava (*Psidium cattleianum*)



Activity #4

Invasive Species Unit 1

Veiled chameleon (*Chamaeleo calyptratus*) Yellow Himalayan raspberry (*Rubus ellipticus*) Yellow jacket (*Vespula pensylvanica*)

#### **Rain Forest**

These wet, windward areas occur from 1,900 to 6,200 feet. Hawaiian forests get between 80 and 390 inches of rain per year. The native plants that evolve here are used to lots of water: lobelias, ferns, '*ōhia* (*Metrosideros polymorpha*), and '*ie*'*ie* (*Freycinetia arborea*). Waikamoi, Olinda, Ha'iku, Huelo, Ke'anae, Nāhiku, Hāna, Kīpahulu, and Upper West Maui Mountains are examples.

Species that can invade this ecosystem include:

African tulip (*Spathodea campanulata*) Boar (*Sus scrofa*) Clidemia (*Clidemia hirta*) Coqui frog (*Eleutherodactylus coqui*) Giant reed (*Arundo donax*) Kahili ginger (*Hedychium gardnerianum*) Miconia (*Miconia calvescens*) (only up to 3,500 feet) Mosquito (*Culex quinquefasciatus*) Polynesian rat (*Rattus exulans*) Black rat (*Rattus rattus*) Strawberry guava (*Psidium cattleianum*) Veiled chameleon (*Chamaeleo calyptratus*) Yellow Himalayan raspberry (*Rubus ellipticus*)

#### **Dryland Forest**

Dryland forests occur at low elevation, from sea level to 3,000 feet. These drier areas get less than 20 inches of rain per year. Temperatures are typically warm to hot. Plants adapted to this climate tend to be drought tolerant and stress resistant: *wiliwili (Erythrina sandwichensis), 'a'ali'i (Dodonaea viscosa), pua kala (Argemone glauca), 'āwikiwiki (Canavalia pubescens)*. Central and Leeward Maui, Kanaio, Makena, Wailea, Kīhei, Mā'alaea, Kahului, Wailuku, Ukumehame, Launiupoko are examples.

Species that can invade this ecosystem include:

Axis deer (*Axis axis*) Boar (*Sus scrofa*) Ivy gourd (*Coccinia grandis*) Fountain grass (*Cenchrus setaceus*) Giant reed (*Arundo donax*) Goat (*Capra hircus*) Mexican creeper (*Antigonon leptopus*) Mosquito (*Culex quinquefasciatus*) Polynesian rat (*Rattus exulans*) Black rat (*Rattus rattus*) Rubber vine (*Cryptostegia grandiflora*) Veiled chameleon (*Chamaeleo calyptratus*)



### Coastal

These areas are close to the ocean so plants must be salt tolerant. Plants that have evolved here tend to be low to the ground due to constant wind. Windward coastal areas may receive up to four times more rain (up to 120 inches per year) than leeward areas, with strong winds being common. Coastal plants such as *hala* (*pandanus tectorius*),  $p\bar{a}$ ' $\bar{u}$  o *Hi*'iaka (*Jacquemontia sandwicensis*) and *naupaka* (*Scaevola sericea*) grow on substrates that range from old coral colonies to basalt cliffs and boulders, and from sandy beaches to lava and ash. Find this ecosystem in the salt spray zone along the coast of Maui.

Species that can invade this ecosystem include:

Axis deer (*Axis axis*) Ironwood (*Casuarina equisetifolia*) Mosquito (*Culex quinquefasciatus*) Polynesian rat (*Rattus exulans*) Black rat (*Rattus rattus*) Veiled chameleon (*Chamaeleo calyptratus*)

## Marine

Marine habitats include coral reefs of various types, boulder fields, sandy bottoms, areas where the reef drops steeply to great depths, caves, caverns, and lava tubes. Native sea plants such as *limu kala* (*Sargassum echinocarpum*) grow here, along with endemic fish such as the saddle wrasse (*Thalassoma duperrey*). From shallow waters found near shore to deeper waters further offshore surrounding Maui.

Species that can invade this ecosystem include: Gorilla ogo (*Gracilaria salicornia*) Red hook seaweed (*Hypnea musciformis*) Roi (*Cephalopholis argus*)



# Teacher Background What About the Natives?

Native Hawaiian plants and animals descended from species that came from elsewhere. They started out as alien species as well! Over time, they evolved into new forms that we now recognize as uniquely Hawaiian. But where did the original ancestral species come from?

To determine that, biologists look around the world for a native species' closest relative. They compare DNA samples of the native species with that of potential ancestors to piece together their "family trees."

For instance, scientists discovered that the magnificent silversword that grows at the summit of Haleakala belongs to the sunflower family. Eventually they determined that the twenty-eight species of the Hawaiian Silversword Alliance (including plants in the genera *Argyroxiphium*, *Dubautia*, and *Wilkesia*) evolved from a single common ancestor: a tarweed from North America.

The origin of some native species is still a mystery.

The following is a list of native Hawaiian species and the location where biologists believe their ancestral species came from:

ʻ <b>Ōhiʻa</b> (Metrosideros polymorpha)	_New Zealand, by way of the Marquesas
<i>Ahinahina</i> , or silversword ( <i>Argyroxiphium sandwicense</i> )	_North America (California)
Koa (Acacia koa)	_Mostly likely Australia
Lobeliads (bellflower family, <i>Campanulaceae</i> )	_ Asia

Hawaiian honeycreepers\_\_\_\_\_Asia





































Activity #4 Invasive Species Unit 1 Acetate Master & Color Copy Master






















### Target Plant Species of the Maui Invasive Species Committee

The Maui Invasive Species Committee (MISC) is a federal-state-private partnership fighting to protect Maui County from invasive plants and animals that threaten our environment, economy, and quality of life. MISC works to:

**PREVENT** invasive species from becoming established on Maui. **CONTROL** invasive species on private and public property free of charge. **EDUCATE** people about invasive species and how to protect Maui.

#### If you encounter any of MISC's Target Species, please call us at 573-MISC.

	What is it?	How can I identify it?	Why is it a problem?	Where is it found?	Is it on the State Noxious Weed List?
Ivy Gourd (Coccinia grandis)	Invasive vine from Asia, Africa, and India	<ul> <li>2-3 inch heart-shaped leaves</li> <li>White flowers with 5 petals, up to 2 inches across.</li> <li>Fruits are red and shaped like cucumbers.</li> </ul>	<ul> <li>Ivy gourd attacks shrubs, trees, fences, and telephone poles.</li> <li>If left unchecked, ivy gourd can form a dense canopy that quickly smothers out its hosts under a solid blanket of vines.</li> <li>Birds eat the fruits and scatter the seeds, contributing to the rapid spread of the vine.</li> <li>It can grow up to 4 inches a day.</li> </ul>	Ivy Gourd is found in dry to moist areas up to 800' elevation.	Yes
Fountain Grass (Pennisetum setaceum)	Bunch- grass from Africa	<ul> <li>Leaves are gray-green and cylindrical</li> <li>Grows in a dense clump</li> <li>Flowers grow in a spike and are purplish when young and white when dry.</li> <li>Grows up to 3 feet tall</li> </ul>	<ul> <li>Fountain grass is drought and fire resistant. Seeds are spread by the wind, animals, vehicles, and people.</li> <li>Fountain grass spreads wild- fires and rapidly regrows, damaging dry forest plants not adapted to fire.</li> <li>It threatens agricultural and natural areas.</li> </ul>	Fountain Grass is found in dry areas from sea-level to 6,500' elevation.	Yes
Giant reed (Arundo donax)	Tall, sugar- cane-like grass from India	<ul> <li>Leaves are 1-2 inches wide and a foot long</li> <li>Has many flowers on 2-ft long, dense, plume-like branches</li> <li>Grows rapidly to over 20 feet in height and spreads quickly</li> <li>Forms large, root masses</li> </ul>	<ul> <li>Giant reed spreads quickly by root pieces in dirt or waterways.</li> <li>It traps sediments and blocks stream flow, leading to erosion and flooding.</li> <li>Once established, giant reed forms dense stands that choke out native plants and can alterwaterbird habitat.</li> <li>It catches on fire easily, spreading wildfires that threaten homes and property.</li> </ul>	Giant reed grows in moist areas and in a wide variety of conditions.	No



### Target Plant Species of the Maui Invasive Species Committee

#### If you encounter any of MISC's Target Species, please call us at 573-MISC.

	What is it?	How can I identify it?	Why is it a problem?	Where is it found?	Is it on the State Noxious Weed List?
Pampas grass (Cortaderia sp.)	Giant bunchgrass from South Africa	<ul> <li>Leaves have sharp, serrated edges</li> <li>Has white to purple flower plumes</li> <li>Grows over 13 feet tall</li> </ul>	<ul> <li>Pampas grass forms dense monotypic stands.</li> <li>Seeds spread rapidly by the wind and can be viable for at least 6 years.</li> <li>Once established, pampas grass can crowd out native plants, damage grazing lands, and create a fire hazard.</li> </ul>	Pampass grass is found from sea level to 9,000' elevation.	Yes
Rubber vine (Cryptostegia undiflora)	Fast- growing climbing plant from Madagascar	<ul> <li>Leaves are shiny, dark green and 2-4 inches long</li> <li>The 2 inch white to lilac flowers have a broad funnel- shaped tube and five lobes.</li> <li>Seeds form tri- angular pods in wing-like pairs 4-5 inches long.</li> </ul>	<ul> <li>It smothers and restricts other plants from growing by winding around trunks, stems and branches.</li> <li>Rubber vine is poisonous. When eaten, it interferes with heart operation in humans and animals. It also causes stomach and intestinal upset. The milky sap can cause burning rashes and blisters. When dry, a powdery dust emerges and can cause coughing, nose swelling and eyelid blisters.</li> </ul>	Rubber vine grows in both dry and moist areas at low eleva- tions. It can reach 50' high.	No
Miconia (Miconia calvescens)	Tree from South and Central America	<ul> <li>The large eye- shaped leaves with 3 obvious leaf veins and purple under- sides</li> <li>Small flowers last for less than a day Grows over 50 feet tall.</li> </ul>	<ul> <li>Miconia shades out and kills other plants trying to grow beneath it.</li> <li>If left unchecked, miconia will create a monotypic forest, destroying rain forests, pastures, and farmlands, and increased erosion and degradation of Maui's healthy watersheds.</li> <li>A single plant produces millions of sand-grain sized seeds each year that remain viable for at least 10 years.</li> </ul>	Miconia is found in wet forests below 2,300' elevation.	Yes



P.O. Box 983, Makawao, HI 96768 Phone: (808) 573-MISC (6472) Fax: (808) 573-6475 Email: miscpr@hawaii.edu Website: www.hear.org/misc/

05/07



# **Got Frogs?** What You Can Do

## Description P

### <u>Problem</u>

Coqui frogs (*Eleutherodactylus coqui*) are native to Puerto Rico and have been invading Maui since 1997.

Photo: MISC

Frogs are round, about the size of a quarter and may grow up to 2" long.

Brown or gray-brown with variable patterns, including a light stripe down the middle of its back.

Found in all types of vegetation from sea-level to 4,000'.

Coqui frogs hide in leaf litter during the day and emerge to elevated perches at night.

Males emit loud twonote mating calls (90 -100 decibels) at night which can be equivalent to a lawnmower running all night long! There are no natural predators to keep populations in check.

Populations can reach densities of 22,000 individuals per acre.

The coqui's loud call destroys the peace and tranquility of the Maui night. Residents and visitors have a difficult time sleeping.

Coqui frogs consume huge quantities of insects, but rarely mosquitoes, disrupting the balance of Maui's vulnerable native ecosystems.

Coqui frogs are a potential food source for snakes and other invasive predators.

Some economic impacts are unhappy tourists decreased local and export plant sales, lower property values, and increased disclosure requirements for property sales.

## Prevention

Ask if plants are coqui-free before you buy or landscape.

Eliminate excess yard debris and ground cover. You can limit frog habitat by removing dead leaves, pruning and thinning shrubs, and raking up debris. Disposing of green waste, fixing leaky faucets and emptying containers that catch rainwater may also decrease chances for frog establishment.

Visit www.hear.org/ frogs or www.ctahr. hawaii.edu/coqui to recognize the coqui frog's call.

Organize community frog squads and night walks to listen for the sound of coqui.

Notify MISC and neighbors of infested areas and offer to help control them.

## <u>Control</u>

If you have a few coqui, follow the calls at night and collect the frogs.

If you have a coqui chorus, spray 12% citric acid (1.0 lbs. per gallon of water) in the area where they are heard. Put water in the sprayer first, then mix in citric acid. Spray must come in contact with the frog's skin to be effective.

MISC will control coqui frogs. Please call 573-6472.

## <u>Report</u>

Report any sightings or calls to the Maui Invasive Species Committee (MISC) at **573-6472**. We want to know:

- Frog's Location
- Number of frogs
- Any action taken

<u>Note</u>: Coqui are illegal to import, breed, keep as pets, sell or export in Hawai'i.

<u>Note</u>: Use of brand names or companies does not imply an endorsement of the product or company. MISC assumes no liability for damage to non-target plants or animals or for any human contact with products mentioned here within.



P.O. Box 983, Makawao, HI 96768 Phone: (808) 573-MISC (6472) Fax: (808) 573-6475 Email: miscpr@hawaii.edu Website: www.mauiisc.org

11/09





WANTED



#### What is it?

- Fountain grass (Pennisetum setaceum) is a bunchgrass from Africa that is invading Hawai'i.
- The gray-green leaves are cylindrical and grow in a dense clump.
- The flowers grow in a spike and are purplish when young and white when dry.
- It grows up to 3 ft tall.
- On Maui, fountain grass is typically found in dry areas from sea-level to 6,500' elevation.

#### Why is it a problem in Hawaiʻi?

- Fountain grass is drought and fire resistant. Seeds are spread by the wind, animals, vehicles, and people.
- Fountain grass spreads wildfires and rapidly regrows, damaging dry forest plants that are not adapted to fire.
- It threatens agricultural and natural areas.
- Fountain grass is on the State noxious weed list.

## What is MISC doing?

- The Maui Invasive Species Committee is a partnership fighting to protect Maui County from invasive plants and animals that threaten our environment, economy, and quality of life.
- MISC works to prevent invasive species from becoming established on Maui.
- MISC controls invasive species on private and public property free of charge.
- MISC educates people about invasive species and how to protect Maui.

#### What can you do?

- Never import or plant fountain grass.
- If you have fountain grass, call MISC and give us permission to control it on your property.
- If you see fountain grass growing or for sale, call MISC.
- Encourage your friends not to buy this or other pest plants so nurseries will stop selling them.
- Learn more. Visit the website http:// www.hear.org/ AlienSpeciesInHawaii/

## Together we can keep "Maui No Ka 'Oi!"





## Giant Reed Call 573-MISC



John M. Randall, photographer, The Nature Conservancy.

#### What is it?

- Giant reed (Arundo donax) is a tall, sugar-cane-like grass from India that is invading Hawai'i.
- The leaves are 1-2 inches wide and a foot long.
- It has many flowers on 2-ft long, dense, plume-like branches.
- This plant grows rapidly and spreads quickly. It can reach heights greater than 20 feet. It forms large, continuous root masses.
- Giant reed grows in moist areas and in a wide variety of conditions.

#### Why is it a problem in Hawaiʻi?

- It spreads quickly by root pieces in dirt or waterways.
- Giant reed traps sediments and blocks stream flow, leading to erosion and flooding.
- Once established, giant reed forms dense stands that choke out native plants and can alter waterbird habitat.
- It catches on fire easily, spreading wildfires that threaten homes and properties.



Ann Murray, illustrator, University of Florida.

## What is MISC doing?

- The Maui Invasive Species Committee is a partnership fighting to protect Maui County from invasive plants and animals that threaten our environment, economy, and quality of life.
- MISC works to prevent invasive species from becoming established in Maui.
- MISC controls invasive species on private and public property free of charge.
- MISC educates people about invasive species and how to protect Maui.



Leaf sheaths, John M. Randall, photographer, The Nature Conservancy.

#### What can you do?

- Never import or plant giant reed.
- If you have giant reed, call MISC and give us permission to control it on your property.
- If you see giant reed growing or for sale, call MISC.
  - Encourage your friends not to buy this or other pest plants so nurseries will stop selling them.
- Learn more. Visit the website http:// www.hear.org/ AlienSpeciesInHawaii/

## Together we can keep "Maui No Ka 'Oi!"



## Ivy Gourd Call 573-MISC







#### What is it?

- Ivy gourd (*Coccinia* grandis) is a vine from Asia, Africa, and India that is invading Hawai'i.
- The 2-3 inch leaves are heart shaped.
- The white flowers have 5 petals, up to 2 inches across.
- The fruits are red and shaped like cucumbers.
- Ivy gourd is a State noxious weed.
- It is found in dry to moist areas up to 800' elevation.

#### Why is it a problem in Hawaiʻi?

- Ivy gourd attacks shrubs, trees, fences, and telephone poles.
- If left unchecked, ivy gourd can form a dense canopy that quickly smothers out its hosts under a solid blanket of vines.
- Birds eat the fruits and scatter the seeds, contributing to the rapid spread of the vine. It can grow up to 4 inches a day.

## What is MISC doing?

- The Maui Invasive Species Committee is a partnership fighting to protect Maui County from invasive plants and animals that threaten our environment, economy, and quality of life.
- MISC works to prevent invasive species from becoming established in Maui.
- MISC controls invasive species on private and public property free of charge.
- MISC educates people about invasive species and how to protect Maui.

#### What can you do?

- Never import or plant ivy gourd.
- If you have ivy gourd, call MISC and give us permission to control it on your property.
- If you see ivy gourd growing or for sale, call MISC.
- Encourage your friends not to buy this or other pest plants so nurseries will stop selling them.
- Learn more. Visit the website http:// www.hear.org/ AlienSpeciesInHawaii/

## Together we can keep "Maui No Ka 'Oi!"







## Miconia Call 573-MISC





#### What is it?

- Miconia (Miconia calvescens) is a tree from South and Central America that is invading Hawai'i.
- The large eye-shaped leaves have 3 obvious leaf veins with purple undersides.
- The small flowers last for less than a day.
- This plant grows to over 50 feet tall.
- Miconia is a State noxious weed.
- It is found in wet forests below 2,300' elevation.

#### Why is it a problem in Hawaiʻi?

- Miconia shades out and kills other plants trying to grow beneath it.
- If left unchecked, miconia will create a monotypic forest, destroying rain forests, pastures, and farmlands, and causing increased erosion and degradation of Maui's healthy watersheds.
- A single plant produces millions of sand-grain sized seeds each year that remain viable for at least 10 years.

## What is MISC doing?

- The Maui Invasive Species Committee is a partnership fighting to protect Maui County from invasive plants and animals that threaten our environment, economy, and quality of life.
- MISC works to prevent invasive species from becoming established in Maui.
- MISC controls invasive species on private and public property free of charge.
- MISC educates people about invasive species and how to protect Maui.

#### What can you do?

- Never import or plant miconia.
- If you have miconia, call MISC and give us permission to control it on your property.
- If you see miconia growing or for sale, call MISC.
- Encourage your friends not to buy this or other pest plants so nurseries will stop selling them.
- Learn more. Visit the website http:// www.hear.org/ AlienSpeciesInHawaii/

### Together we can keep "Maui No Ka 'Oi!"







## Pampas Grass Call 573-MISC





#### What is it?

- Pampas grass (*Cortaderia sp.*) is a giant bunchgrass from South America that is invading Hawai'i.
- The narrow leaves have sharp, serrated edges.
- It has white to purple flower plumes.
- This plant grows to over 13 feet tall.
- Seeds are spread by the wind and can be viable for at least 6 years.
- *Cortaderia jubata* is on the State noxious weed list.

#### Why is it a problem in Hawaiʻi?

- Pampas grass forms dense monotypic stands.
- Spreads rapidly.
- Seeds are dispersed by wind up to 20 miles away.
- Once established, pampas grass can crowd out native plants, damage grazing lands, and create a fire hazard.

## What is MISC doing?

- The Maui Invasive Species Committee is a partnership fighting to protect Maui County from invasive plants and animals that threaten our environment, economy, and quality of life.
- MISC works to prevent invasive species from becoming established in Maui.
- MISC controls invasive species on private and public property free of charge.
- MISC educates people about invasive species and how to protect Maui.



Cortaderia selloana

#### What can you do?

- Never import or plant pampas grass.
- If you have pampas grass, call MISC and give us permission to control it on your property.
- If you see pampas grass growing or for sale, call MISC.
- Encourage your friends not to buy this or other pest plants so nurseries will stop selling them.
- Learn more. Visit the website http:// www.hear.org/ AlienSpeciesInHawaii/

## Together we can keep "Maui No Ka 'Oi!"



P.O. Box 983, Makawao, HI 96768 Phone: (808) 573-MISC (6472) Fax: (808) 573-6475 Email: miscpr@hawaii.edu Website: www.mauiisc.org

10/06



## **Rubber Vine** Call 573-MISC





Flower, seed pods, and leaves.

#### What is it?

- Rubber vine (Cryptostegia grandiflora) is a fastgrowing climbing plant from Madagascar that is invading Hawai'i.
- The shiny, dark green leaves are 2-4 inches long.
- The 2 inch white to lilac flowers have a broad funnel-shaped tube and five lobes.
- Seeds form in triangular pods in wing-like pairs 4-5 inches long.
- Rubber vine grows in both dry and moist areas at low elevations. It can reach 50 feet high. Seeds spread by wind and water.

#### Why is it a problem in Hawai'i?

• It smothers and restricts other plants from growing by winding around trunks, stems and branches.

Rubber vine is poisonous. When eaten, it interferes with heart operation in humans and animals. It also causes stomach and intestinal upset. The milky sap can cause burning rashes and blisters. When dry, a powdery dust emerges and can cause coughing, nose swelling and eyelid blisters.

#### What is MISC doing?

- The Maui Invasive Species Committee is a partnership fighting to protect Maui County from invasive plants and animals that threaten our environment, economy, and quality of life.
- MISC works to prevent invasive species from becoming established in Maui.
- MISC controls invasive species on private and public property free of charge.
- MISC educates people about invasive species and how to protect Maui.

#### What can you do?

- Never import or plant rubber vine.
- If you have rubber vine, call MISC and give us permission to control it on your property.
- If you see rubber vine growing or for sale, call MISC.
  - Encourage your friends not to buy this or other pest plants so nurseries will stop selling them.
- Learn more. Visit the website http:// www.hear.org/ AlienSpeciesInHawaii/

### Together we can keep "Maui No Ka 'Oi!"





## Veiled Chameleons are invading Maui! Chameleons eat birds, plants and native insects. Don't let this invasive species be your newest neighbor!

Veiled chameleons pose a threat to Maui because they can live in a wide range of habitats, from sea level to over 10,000' elevation, and their large size allows them to prey upon Native Hawaiian birds, plants and insects. Also, females may lay 30—95 eggs up to three times a year. Veiled chameleons have been found on Maui. If you see a veiled chameleon, capture it, contain it, and immediately call Maui Invasive Species Committee 573-MISC.



Native to Yemen and Saudi Arabia, veiled chameleons are invasive and illegal on Maui. It is against the law to import, breed, keep as pets, sell or export veiled chameleons. Penalties include up to \$200,000 and 3 years in prison. The Hawai`i Department of Agriculture (HDOA) has an amnesty program where someone can turn in an illegal animal without fear of prosecution. Call HDOA at 873-3555.

#### Here's how to tell the difference between Veiled and Jackson's chameleons

Please report only veiled chameleon sightings. Jackson's chameleons are a common species.

#### Veiled chameleons:

- Bony shark-fin-like shield on its head.
- Fleshy fringe from under its nose down the middle line of its belly to the base of its tail.
- Legs are long and pencil thin, and it has a long thin tail. Males have little nubs on its back feet.
- Large adults most times have vertical stripes.
- Grows up to 2 feet in length.
- Juveniles are usually light green with a prominent shield on its head.





Adult male (left) and female (right) Jackson's chameleon.

#### Jackson's chameleons:

- Adult males have three horns on head.
- Some have irregular splotchy patterns on the body.
- When handled or under stress, a red color appears on folds under its neck.
- Legs are shorter than veiled chameleons and stocky.
- Grows up to 10 inches in length.
- Juveniles are usually brown or tan.



P.O. Box 983, Makawao, HI 96768 Phone: (808) 573-MISC (6472) Fax: (808) 573-6475 Email: miscpr@hawaii.edu

Activity #4 Invasive Species Unit 1

# Exercise 1: Where Do They Come From?

Below you'll find a list of invasive species that are now found in Hawai'i. Where did they come from? Do some research to find out. Map their origins below. Draw a line from each plant or animal's place of origin and suggest a possible **vector**, or means of **dispersal**. For instance, do you think miconia seeds blew here on the wind or did someone bring a live plant over on the plane? Create a legend to indicate the various vectors.

Coqui frog (*Eleutherdactylus coqui*) Fountain grass (*Cenchus setaceus*) Ivy gourd (*Coccinia grandis*) Miconia (*Miconia calvescens*) Pampas grass (*Cortaderia jubata*) Rubber vine (*Cryptostegia grandiflora*) Veiled chameleon (*Chamaeleo calyptratus*)



Activity #4
 Invasive Species Unit 1



## Exercise 2: Where Can They Invade?

Common Name:	
Scientific name:	
Description:	

Origin:\_\_\_\_\_

Preferred climate type:\_\_\_\_\_

Rainfall:

Elevation:\_\_\_\_\_\_ Impacts in Hawai'i:\_\_\_\_\_\_

Ecosystems this species can invade in Hawai'i:\_\_\_\_\_

## Exercise 2: Where Can They Invade?

Once a plant or animal species arrives on our shores, it has to settle in suitable habitat in order to survive. It needs the right amount of rain, sunlight, and heat, in addition to the adequate food, mates, and/ or pollinators. Below are descriptions of ecosystems found on Maui. Which one(s) can your species invade?

## Maui Ecosystems

#### **Alpine Aeolian**

This high-altitude region of Maui is characterized by sparse vegetation and an extreme climate with widely varying daily temperatures, intense solar radiation, and an average of 30-50 inches of rain per year. Few plants thrive here: the spectacular Haleakalā silversword or 'āhinahina (Argyroxiphium sandwicense subsp. macrocephalum), 'ōhelo (Vaccinium reticulatum), hinahina (Artemisia australis), and kupa'oa (Dubautia ciliolata). This describes the summit of Haleakalā, above 7,500 feet.



Haleakalā National Park (Photo: Forest and Kim Starr)



Auwahi Forest Preserve (Photo: Forest and Kim Starr)

### **Mesic Forest**

Mesic forests occur on both East and West Maui, mostly between 2,500-4,100 feet elevation, with between 40 to 100 inches of rain per year. Before human contact, this was probably the most botanically diverse of all Hawaiian forests. Koa (Acacia koa), 'ōhi'a (Metrosideros *polymorpha*), and sandalwood or *iliahi* (Santalum haleakalae) trees are common, in addition to a mixture of plants adapted to both wet and dry areas such as *maile* (Alyxia stellata) and halapepe (Pleomele auwahiensis). Good examples can be found in East Kaupo gap, Kahikinui, upper Auwahi and 'Ulupalakua, Polipoli, and Makawao Forest Reserve.

Activity #4 Invasive Species Unit 1





Thick forest understory in East Maui (Photo courtesy of Shannon Wianecki)

#### **Rain Forest**

These wet, windward areas occur from 1,900 to 6,200 feet. Hawaiian forests get between 80 and 390 inches of rain per year. The native plants that evolve here are used to lots of water: lobelias, ferns, 'ōhia (Metrosideros polymorpha), and 'ie'ie (Freycinetia arborea). Waikamoi, Olinda, Ha'iku, Huelo, Ke'anae, Nāhiku, Hāna, Kīpahulu, and Upper West Maui Mountains are examples.

#### **Dryland Forest**

Dryland forests occur at low elevation, from sea level to 3,000 feet. These drier areas get less than 20 inches of rain per year. Temperatures are typically warm to hot. Plants adapted to this climate tend to be drought tolerant and stress resistant: *wiliwili (Erythrina sandwichensis), 'a'ali'i (Dodonaea viscose), pua kala (Argemone glauca), 'āwikiwiki (Canavalia pubescens)*. Central and Leeward Maui, Kanaio, Makena, Wailea, Kīhei, Mā'alaea, Kahului, Wailuku, Ukumehame, Launiupoko are examples.



Wiliwili trees at Puʻu o Kali (Photo courtesy of Maui Invasive Species Committee)

Activity #4 ` Invasive Species Unit 1

#### Coastal

These areas are close to the ocean so plants must be salt tolerant. Plants that have evolved here tend to be low to the ground due to constant wind. Windward coastal areas may receive up to four times more rain (up to 120 inches per year) than leeward areas, with strong winds being common. Coastal plants such as hala (pandanus tectorius), pā'ū o Hi'iaka (Jacquemontia sandwicensis) and naupaka (Scaevola sericea) grow on substrates that range from old coral colonies to basalt cliffs and boulders, and from sandy beaches to lava and ash. Find this ecosystem in the salt spray zone along the coast of Maui.



Waihe'e Coast (Photo courtesy of Maui Invasive Species Committe)



Cauliflower corals (Pocillopora meandrina) (Photo courtesy of Lissa Strohecker)

#### Marine

Marine habitats include coral reefs of various types, boulder fields, sandy bottoms, areas where the reef drops steeply to great depths, caves, caverns, and lava tubes. Native sea plants such as *limu kala* (*Sargassum echinocarpum*) grow here, along with endemic fish such as the saddle wrasse (*Thalassoma duperrey*). From shallow waters found near shore to deeper waters further offshore surrounding Maui.



### Activity #5

## Invasive Species Jeopardy

#### Length:

Two class periods

#### **Prerequisite Activity:**

Invasive Species Module Unit 1 Activity #4 "Where Do They Come From? Where Can They Invade?"

Note: If you did not do the prerequisite activity above, you can use the flyers provided in that activity in place of student-generated cards.

#### **Objectives:**

- Investigate relationships between native Hawaiian and invasive species.
- Become familiar with invasive species, their origins, and characteristics.
- Use knowledge gained to create jeopardy questions.

#### Vocabulary

Characteristics	Impacts	Origins
Ecosystem	Invasive	

## • • • Class Period One: Creating Questions

### Materials & Setup

• Student-generated cards or flyers provided with Invasive Species Module Unit 1 Activity #4 "Where Do They Come From? Where Can They Invade?"

#### Instructions\_

- Divide the class into five teams. Tell students they will invent "Jeopardy" game clues and answers based on the cards they made (or flyers provided) for Invasive Species Module Unit 1 Activity #4 "Where Do They Come From? Where Can They Invade?"
- 2) Before playing the game, each team will have a chance to review the information on the cards (or flyers). Teams are assigned the following categories:

Team #1 – Plants Team #2 – Animals Team #3 – Origins Team #4 – Ecosystem Impacts Team #5 – Invasive Characteristics

3) Each team will create clues and answers related to their category. There are five clues per round. Clues fall into increasing levels of difficulty: 10, 20, 30, 40, and 50 points. Clues are written as

Activity #5 Invasive Species Unit 1



statements and their answers are framed as questions. Sample clue: This bunch grass has sharp edges and can grow up to 10 feet tall. Answer: What is pampas grass (*Cortaderia jubata*)?

- For each round you'd like to play, ask teams to create five clues. Eg: fifteen clues for three rounds. Create a few "Double Jeopardy" clues of your own to insert randomly during the game. (See Teacher Background "Round 1" for examples.)
- 5) Have students keep their clues and answers secret from the other teams.

## • • • Class Period Two: Playing Invasive Species Jeopardy

Materials & Setup-

- Student-generated cards or flyers provided with Invasive Species Module Unit 1 Act #4 "Where Do They Come From? Where Can They Invade?"
- Master Acetate "Invasive Species Jeopardy Rules" (p. 138)
- "Invasive Species Jeopardy Slideshow" or Master Acetate "Game Board" (duplicated for each round) (p. 139)
- Overhead projector and screen
- Stopwatch or a watch with a second hand

### Instructions for playing Jeopardy\_

Note: Round 1 clues and answers have been provided as an example. Choose at random where to insert your Double Jeopardy clues.

- 1) Review the object, rules, and procedures for the game with students using the instructions given here and the rules on the Teacher Background "Invasive Species Jeopardy Rules" acetate (p. 138).
- Use either the "Invasive Species Jeopardy Slideshow" or Game Board Acetate to begin the game. Cross off each category and point value as it is selected. Read the corresponding statement from "Invasive Species Jeopardy Round 1."

To use the slideshow: Open the file "Invasive Species Jeopardy Slideshow," on the DVD included with this curriculum. Click "Slide Show" in the menu and select "View Show" OR press F5. "Click to Begin" in the bottom right corner of the Jeopardy title page.

Move the arrow cursor over the category to the students' chosen point value. Notice the cursor "arrow" change to a hand when rolling over the point value. Click on the chosen point value when the cursor changes to a hand. After clicking on the point value, the answer will appear. When you want to reveal the question (to verify the student's response), make sure the cursor is a "hand" by pointing it off of the text before clicking.

To return to the main game page, click away from the text, with the cursor as a "hand." (If you click on the answer with the cursor as an "arrow," the screen will continue to cycle through all of the answers and questions revealing that information.)

- 3) Teams have 15 seconds to respond to clues. Continue play by following the rules, and keep score. The team with the largest score wins.
- 4) Play subsequent rounds in the same manner, using a fresh game board and clues.

Note: To create additional Jeopardy rounds with new answers and questions, save the slideshow file with a new name and follow the instructions on the second slide.

5) Stop whatever round is in session at the end of the first class period, and determine a winner for whatever rounds have been played.



## Ieacher Background Invasive Jeopardy Round 1

#### Plants — Round 1 10 points This bunch grass has sharp edges and can grow up to 10 feet tall. What is pampas grass (*Cortaderia jubata*)?

#### 20 points

This plant's giant, umbrella-like leaves have purple undersides. What is miconia (*Miconia calvescens*)?

#### 30 points

The blades of this grass are cylindrical. What is fountain grass (*Cenchus setsceus*)?

#### 40 points

This plant can be identified by its wing-like pairs of seedpods. What is rubber vine (*Cryptostegia grandiflora*)?

#### 50 points

This plant can grow four inches a day. What is ivy gourd (*Coccinia grandis*)?

#### Animals — Round 1

#### 10 points

This noisy animal keeps people up at night with its piercing, two-note mating call. What is a coqui frog (*Eleutherdactylus coqui*)?

#### 20 points

Keeping this animal is against the law and could cost you \$200,000 or three years in prison. What is a veiled chameleon (*Chamaeleo calyptratus*)?

#### 30 points

Veiled chameleons (*Chamaeleo calyptratus*) can grow up to this long. What is two feet?

#### 40 points

This common household chemical is used to control coqui frogs (*Eleutherdactylus coqui*). What is citric acid?

Activity #5 Invasive Species Unit 1



#### 50 points

Veiled chameleons (*Chamaeleo calyptratus*) are different from Jacksons' chameleons. Instead of horns, veiled chameleons have this on their head.

What is a bony, shark-like shield?

#### Origins — Round 1

#### 10 points

Coqui frogs (*Eleutherdactylus coqui*) are celebrated here, in their native country. What is Puerto Rico?

#### 20 points

Pampas grass (*Cortaderia jubata*) is named for the grassy plains beneath these South American mountains.

What are the Andes?

#### 30 points

Fountain grass (*Pennisetum setaceum*) is suited to the hot, dry climate found in its native home. What is North Africa?

#### 40 points

Veiled chameleons (*Chamaeleo calyptratus*) come from the mountainous regions of these countries.

What are Yemen and Saudi Arabia?

#### 50 points

Rubber vine (*Cryptostegia grandiflora*) hails from this large island nation, which is also home to lemurs.

What is Madagascar?

#### Ecosystem Impacts — Round 1

#### 10 points

Ivy gourd (*Coccinia grandis*) climbs other plants and does this to them. What is smother?

#### 20 points

Veiled chameleons (*Chamaeleo calyptratus*) are large lizards and can prey on these types of species.

What are plants, insects, and birds?

#### 30 points

The shallow roots of miconia (*Miconia calvescens*) don't function the same as a spongy mat of understory plants. Instead, they encourage these problems after a heavy rain.

What are erosion and run-off?



#### Activity #5

Invasive Species Unit 1

#### 40 points

If snakes were to escape into the wild in Hawai'i, coqui frogs (*Eleutherdactylus coqui*) could serve as this for them.

What is a food source?

#### 50 points

Wind whipping through the dead, dry leaves of fountain grass (*Pennisetum setaceum*) creates this condition.

What is a fire hazard?

#### Invasive Characteristics — Round 1

#### 10 points

You can almost watch vines like ivy gourd (*Coccinia grandis*) spread because of this quality. What is fast growing?

#### 20 points

Both pampas (*Cortaderia jubata*) and miconia (*Miconia calvescens*) produce tens of thousands of seeds every year—an example of this characteristic.

What is highly fertile?

#### 30 points

Some plants, like miconia (*Miconia calvescens*), don't require much sunlight to grow. This characteristic allows them to grow just about anywhere.

What is shade-tolerant?

#### 40 points

Rubber vine (*Cryptostegia grandiflora*) doesn't just cover acreage with impenetrable thickets, it also possesses this quality—making it dangerous to human health and safety.

What is toxic?

#### 50 points

Coqui frog (*Eleutherdactylus coqui*) populations are kept in check in Puerto Rico. But in Hawai'i, they grow out of control because they lack these.

What are predators?

#### **DOUBLE JEOPARDY**

Some invasive plants, such as miconia (*Miconia calvescens*), have the ability to eliminate the other species in the forest, creating this.

What are monostands?

The fruits of this plant are red and shaped like small cucumbers. What is ivy gourd (*Coccinia grandis*)?


## **Invasive Species Jeopardy Rules**

#### Object

Accumulate the largest amount of points by providing correct responses in 15 seconds or less.

#### Rules

- Each team selects a spokesperson to read the team's clues and give official answers. The spokesperson may consult with team members, but only the spokesperson's response will count.
- Team #1 begins the game, choosing any category besides its own. Play progresses in numeric order through the teams.
- Select a category and a point amount. The appropriate team's spokesperson will read the clue. Your team will have 15 seconds to respond. Your response must be framed as a question. For example: Statement:
   This bunch grass has sharp edges and can grow up to 10 feet tall.
   Your answer:
   What is pampas grass (*Cortaderia jubata*)?
- If your answer is correct, the point amount is added to your team's total score and your team selects another category and point amount, attempting to answer that clue. Your team continues as long as you answer the clues correctly. (For answers that involve species names, you may correctly state the Hawaiian, English or Latin name.)
- If you answer incorrectly, the next team in numerical order gets 15 seconds to answer the same statement (skipping the team who created the clue and answer.) Correct answers always result in adding the point amount to the answering team's score and selecting a new question. Incorrect answers always result in subtracting the point amount and the next team getting a chance to answer the same statement. If none of the teams can answer a statement correctly, the team who created the question will read the correct response and play continues with the team whose turn it was when that statement was first read.
- DOUBLE JEOPARDY. In each round, there is one "double jeopardy" clue. If your team chooses the double jeopardy clue, you may decide to bet a portion or all of your total score. Tell the class how much you are betting. If you answer the clue correctly, you add that amount to your score. If you answer incorrectly, subtract that amount from your score.
- Play continues until all clues have been answered or time runs out.



## Game Board

Plants	Animals	Origins	Ecosystem Impacts	Invasive Characteristics
10	10	10	10	10
points	points	points	points	points
20	20	20	20	20
points	points	points	points	points
30	30	30	30	30
points	points	points	points	points
40	40	40	40	40
points	points	points	points	points
50	50	50	50	50
points	points	points	points	points

## SCORE

Team #1:

Team #2:

Team #3:

Team #4:

Team #5:



### Activity #6

# Mascots, Icons, and 'Aumakua

#### Length:

One class period

#### **Prerequisite Activity:**

None

#### **Objectives:**

- Demonstrate understanding of native and non-native species.
- Practice critical thinking skills with regard to mascot choices.
- Investigate Hawaiian cultural connections to animals.
- Develop reading comprehension.

#### Vocabulary

'Aumakua	Mana
Icon	Mascot

## • • • Class Period One: Learning About Names

Materials & Setup-

For each student

- Student Pages "Mascots, Icons, and 'Aumakua" (pp. 145-147)
- Student Pages "The 'Aumakua Hawaiian Ancestral Spirits" by Herb Kāne (Courtesy of Hawai'i Division of Aquatic Resources, ©2004) (pp. 148-149)

### Instructions -

- 1) Pass out the Student Pages "Mascots, Icons, and '*Aumakua*" and "The '*Aumakua* Hawaiian Ancestral Spirits by Herb Kane." Go over the answers for page one in class, and then allow students to finish on their own. (They will need access to the Internet or a library.)
- 2) Ask students what they know about their school's mascot: Why might the school have opted for that particular mascot? When was it chosen? Who chose it? If it is an animal, is it native to Hawai'i? Do they feel the mascot is an appropriate representative of the student body? Why or why not? What qualities does it embody? Have students write a list.
- 3) Have students name all the native Hawaiian plant, animal, bird, fish, or insect species they can think of that embody the qualities they listed, or other commendable qualities.
- 4) Allow students to vote for a class mascot based on what they've brainstormed.



Activity #6

Invasive Species Unit 1

## Journal Ideas

- Write a story, using the 'aumakua legend as an example.
- How might cultural traditions, such as the Hawaiian belief in *'aumakua*, influence how a culture treats its natural resources?

## Assessment Tools

- Participation in class discussion
- Student pages
- Journal entries



## Teacher Version Mascots, Icons, and 'Aumakua



The **icons** for this curriculum were carefully chosen: a wolf spider for the module concerning the Alpine-Aeolian habitat, an ' $\bar{a}kohekohe$  (crested honeycreeper) for the Rain Forest module, a green sea turtle for Coastal, and a *humuhumunukunukuāpua* 'a for Marine. Each of these native species is emblematic of the ecosystems it represents. For the invasive species module, a fire ant was chosen because it's one of the alien pests that threatens native Hawaiian habitats.

What is the purpose of choosing a **mascot** or symbol? List several reasons.

- To create a sense of pride
- To represent a particular place
- To evoke admirable qualities, such as courage, persistence, or nobility
- To spotlight something that needs attention, for example, an endangered species

What is your school mascot?

Do you agree with your school's choice of mascot? Why or why not?

[Any well-thought-out answer will suffice.]

What are the qualities it represents? Possible answers:

fierceness loyalty duty nobility courage perseverance uniqueness strength grace resourcefulness wisdom power

#### Activity #6

Invasive Species Unit 1



Name some Hawaiian species—birds, fish, mammals, insects, or plants—that have similar qualities and identify those characteristics.

Suggestions:
'Āhinahina, silversword: plant evolved to survive extreme winds, snow, and solar radiation; possesses spectacular, sweet-scented blooms
Ulua: fierce fighter, long-distance swimmer
'Io, Hawaiian hawk: regal, excellent vision
Pueo, Hawaiian short-eared owl: graceful, excellent hunter
Puhi, moray eel: colorful, fierce defender of its territory
Manō, tiger shark: fierce, powerful, graceful
'O'opu: Hawaiian goby: tenacious fish that climbs 100-foot waterfalls
Koa tree: strong, keystone species, captures moisture from air to nourish watershed, valuable wood, used to make voyaging canoes
'Ōhi'a tree: beautiful, keystone species, provides food and shelter for native birds and insects, used to make house posts
Happy-faced spider: stylish, friendly seeming, unique in the world

Find the answers for the following:

National bird: American bald eagle (*Haliaeetus leucocephalus*) Hawai'i State bird: Hawaiian goose, nēnē (Branta sandvicensis) Hawai'i State mammal: Hawaiian monk seal (Monachus schauinslandi) Hawai'i State fish: humuhumunukunukuāpua'a, trigger fish (Rhinecanthus rectangulus) Hawai'i State flower: yellow hibiscus, ma'o hau hele (Hibiscus brackenridgei) Hawai'i State motto: Ua Mau ke Ea o ka 'āina i ka Pono (The life of the land is perpetuated in righteousness) Hawai'i Island lei: lei 'ohia lehua (Metrosideros polymorpha) Maui lei: *lei lokelani*, damask rose, (*Rosa damascena*) Molokai lei: *lei kukui*, candlenut tree, (*Aleurites moluccana*) Lānai lei: lei kaunaoa, Hawaiian dodder, (Cuscuta sandwichiana) Kahoʻolawe lei: *lei hinahina*, Hawaiian heliotrope, (*Heliotropium anomalum*) Molokini lei: *lei kala*, sargassum, (*Sargassum echinocarpum*) O'ahu lei: *lei 'ilima (Sida fallax)* Kaua'i lei: *lei mokihana (Rutaceae Melicope anisata)* Ni'ihau lei: lei pūpū, Ni'ihau shell

Choose an item from the list above. Write a paragraph supporting or disagreeing with its selection as a mascot or representative. If you disagree with it, suggest a replacement and give reasons for why your choice would serve as a better representative.





In Hawai'i, people often refer to animals such as sharks, turtles, or owls as their '*aumakua*, or guardian spirits. According to Hawaiian tradition, '*aumakua* are deified ancestors that appear in the form of specific animals, plants, or natural phenomena such as clouds, rainbows, or wind. Many myths and stories describe the protective powers of these '*aumakua*. Read the following story by Hawaiian cultural leaders Herb Kāne.

Does your family have an 'aumakua or do you know of any families with 'aumakua?

[any well-thought-out answer will suffice]

How does the Hawaiian tradition of recognizing and honoring *'aumakua* differ from the Western custom of choosing a mascot or state animal? How is it similar?

Hawaiians believe that 'aumakua are their ancestors, invisible spirits that inhabit an animate or inanimate form (such as a rock, rainbow, plant, or animal). They are not chosen, but inherited along with the family's genealogy. Western mascots are animals, plants, or natural phenomena that are chosen for their inspiring qualities. Both 'aumakua and mascots symbolize honorable traits.

How does Herb Kane define mana in his essay?

Mana was the force that powered the universe, expressed in everything from the movements of stars to the growth of a plant or the surge of a wave. Human mana = life force, charisma, inherited talents, intelligence, and other virtues Certain talents within a family passed down the line of seniority

According to Kane, how do 'aumakua help people? Name five ways.

'Aumakua might help canoe makers, physicians, and kapa makers do their work. They could bring warnings of impeding danger, comfort in times of sorrow, or be helpful in other ways: chase fish into nets, guide a lost canoe to safety.

Activity #6 Invasive Species Unit 1

Mascots, Icons, and 'Aumakua



The **icons** for this curriculum were carefully chosen: a wolf spider for the module concerning the Alpine-Aeolian habitat, an ' $\bar{a}kohekohe$  (crested honeycreeper) for the Rain Forest module, a *honu* (green sea turtle) for Coastal, and a *humuhumunukunukuāpua*'a (trigger fish) for Marine. Each of these native species is emblematic of the ecosystems it represents. For the invasive species module, a fire ant was chosen because it's one of the alien pests that threatens native Hawaiian habitats.

What is the purpose of choosing a **mascot** or symbol? List several reasons.

What is your school mascot?

Do you agree with your school's choice of mascot? Why or why not?

What are the qualities it represents?



Name some Hawaiian species—birds, fish, mammals, insects, or plants—that have similar qualities and identify those characteristics.

Find the answers for the following:

National bird:
Hawai'i State bird:
Hawai'i State mammal:
Hawai'i State fish:
Hawai'i State flower:
Hawai'i State motto:
Hawaiʻi Island lei:
Maui lei:
Molokai lei:
Lanai lei:
Kahoʻolawe lei:
Molokini lei:
Oʻahu lei:
Kauaʻi lei:
Ni'ihau lei:

Choose an item from the list above. Write a paragraph supporting or disagreeing with its selection as a mascot or representative. If you disagree with it, suggest a replacement and give reasons for why your choice would serve as a better representative.



In Hawai'i, people often refer to animals such as sharks, turtles, or owls as their '*aumakua*, or guardian spirits. According to Hawaiian tradition, '*aumakua* are deified ancestors that appear in the form of specific animals, plants, or natural phenomena such as clouds, rainbows, or wind. Many myths and stories describe the protective powers of these '*aumakua*. Read the following story by Hawaiian cultural leader Herb Kāne.

Does your family have an 'aumakua or do you know of any families with 'aumakua?

How does the Hawaiian tradition of recognizing and honoring '*aumakua* differ from the Western custom of choosing a mascot or state animal? How is it similar?

How does Herb Kane define mana in his essay?

According to Kane, how do 'aumakua help people? Name five ways.

Activity #6 Invasive Species Unit 1

# The 'Aumakua — Hawaiian Ancestral Spirits by Herb Kawainui Kāne

Herb Kawainui Kāne is an author and artist-historian with special interest in Hawai'i and the South Pacific. He resides in rural South Kona on the island of Hawaii.

Research on Polynesian canoes and voyaging led to his participation as general designer and builder of the sailing canoe Hōkūle'a, on which he served as its first captain. Hōkūle'a has made a number of round trip voyages to South Pacific destinations, including a 16,000 mile pan-Polynesia voyage to New Zealand and back, and a trip to Rapa Nui (Easter Island), all navigated without instruments.

In 1984 he was elected a Living Treasure of Hawaii. In the 1987 "Year of the Hawaiian" celebration, he was one of 16 persons chosen as Po'okela (Champion).

Herb was a member of the state's Shark Task Force, and wrote this paper for the other members to explain the cultural significance of sharks.



Pre-Christian Polynesians saw themselves as the living edge of a much greater multitude of ancestors who, as ancestral spirits, linked the living to a continuum going back to the first humans, to the major spirits, and thence to the ultimate male and female spirits that created the universe. To Polynesians there was no supernatural; the entire universe and all things in it, including spirits, were natural.

Mana was the force that powered the universe - expressed in everything from the movements of stars to the growth of a plant or the surge of a wave. Human mana - manifested as life force, charisma, inherited talents, intelligence, and other virtues - flowed down the same hereditary channel of seniority from the major spirits (akua) to the ancestral spirits ('aumakua) to living p a r e n t s  $(m\bar{a}kua)$  and their children. The inheritance of certain talents within a family was taken as evidence of mana being passed down the line of seniority. Canoe makers would pray to ancestors noted for their skill as canoe makers; physicians would pray to ancestors who were famous healers; kapa makers would pray to ancestors who were outstanding artists in kapa making.1

Authority was based on seniority-descending the channels of mana flow from the major gods to the youngest child. The elder brother's authority over the younger was challenged only when the elder acted with unwarranted cruelty or against norms of acceptable behavior-actions which signified that the elder had lost the mana which gave him the right to rule over his junior. Parents had authority over their children, and clan elders ruled the extended families. Chiefly clans, by virtue of genealogies connecting them more directly with the major gods, were considered as elder to the clans of commoners.<sup>2</sup> Both chiefs and commoners venerated their more illustrious ancestors as 'aumakua, and sought their aid.

*'Aumakua* were invisible to the living, but able to possess or inhabit many visible forms, animate or inanimate. A rock or a small carved image set up in a family shrine within the home might serve as a resting place for *'aumakua*. The *momoa*, the pointed stern of a canoe hull which projects aft from below the rear hull covering of a Hawaiian canoe, was regarded as the "seat" for the invisible *'aumakua* of the canoe's owner.<sup>3</sup> The war club of a famous warrior ancestor might be powered by his *mana* when wielded by a descendant in battle.

*'Aumakua* could also take possession of living creatures. Unusual experiences with c e rtain fish, birds, reptiles, insects or mammals may have led some Hawaiians to regard certain animals as forms favored by their *'aumakua*. Thus it was believed that ancestral spirits could make appearances to express parental concern for the living, bringing warnings of impending danger, comfort in times of stress or sorrow, or in other ways being helpful. This is not to say that an entire species was regarded as *'aumakua* – only that an individual animal might be possessed by an *'aumakua*, and then only as the occasion might demand.

Some families, for example, believed that the spirit of an ancestor could appear as a shark, perhaps to chase fish into their nets, or to guide a lost canoe to safety. This does not imply that these families regarded all sharks as their 'aumakua; neither does it mean that a particular shark was an 'aumakua. To be precise, it means that an 'aumakua had chosen to take possession of a particular shark for a particular purpose. But for these families, the killing or eating of any shark was an act of filial disrespect, for which the 'aumakua might punish them by bringing sickness upon the transgressors.

Some *akua*, in particular Laka, Pele, and Hi'iaka, were – and still are – regarded as *'aumakua* by certain families.

Both 'aumakua and akua dwelled in the Po, the timeless, measureless, eternity which existed before the universe was created, and to which spirits of the dead returned. B u t some 'aumakua maintained a protective and beneficial parental interest in the welfare of their living descendants. However, if the 'aumakua were not paid acts of respect, they might, as indignant parents, visit some punishment upon the living, or they might simply lose interest and drift away into the limitless Po, beyond the call of their descendants. One showed such respect by living in a manner that emulated the virtues of one's ancestors. One showed appreciation for having received an inherited talent by submitting to rigorous training, and by industriously applying one's skill. Such acts would attract the proud parental interest of ancestral spirits, who would reward their respectful descendants with mana.

Offering prayers in which certain ancestors were specifically addressed by their names also showed respect. Before the abandonment of the official religion in 1819, and the subsequent acceptance of Christianity, prayers to the major akua were often directed first to 'aumakua, calling them by name and invoking their aid to pass these communications up the line of seniority. That Hawaiians knew many of their 'aumakua by name well into the 20th century (Mary Kawena Pūku'i learned the names of 50 'aumakua as a child) is evidence that the acceptance of Christianity did not force the abandonment of 'aumakua beliefs.<sup>4</sup> The explanation is found in the words of Christian doctrine. References to God as "Father," and the commandment to "honor thy parents all the days of thy life" found immediate acceptance from Hawaiians who perceived an area of agreement between the new religion and Polynesian extended family values.

Another act of respect was the sharing of food. All Polynesians propitiated ancestral

spirits by ritual feeding; spirits who were not "fed" would fade away beyond call. Foods were placed before small domestic shrines to thea *'aumakua*, as well as upon altars of chiefly chapels and the altars within great temples to the major gods. As a boy, I knew a fishing family in Puna whose elder male carried food down to the shore every evening, where he called to a shark, and fed it.<sup>5</sup>

A charming folktale describes how two children, a brother and sister, were captured by enemies of their chief and tied to a stake. That night an *'aumakua* came to them as an owl, and unfastened their bonds with its beak. Then it led them away, but cautioned them to walk backwards. The next day, their enemies could find no footprints except those that seemed to lead toward the place of their captivity, so the search had to be abandoned.

#### ENDNOTES

- 1. Many specializations were organized as guilds, each headed by a *kahuna* (leading expert, or master) who also served as interfaces between the living and the spirits, bearing gifts to the *heiau* and petitioning patron spirits of their guilds for *mana* for the living practitioners very similar to the guildmasters of Europe, who, bearing gifts to the cathedral, prayed to the patron saints of their guilds for success for their members.
- 2. Of the five classes of Hawaiian chiefs, the highest ranking (nī 'aupi'o) were those with the most perfect genealogies—clear channels for the flow of mana. This was vital to everyone, chiefs and commoners alike; all believed that success or disaster for the entire community rested on the capacity of their ruling chief to receive chiefly mana from the gods and his ancestors.

Commoners had chiefly ancestors, but they were commoners because their genealogies had become lost or obscured; thus the flow of chiefly *mana* was blocked and could not descend to them.

This belief formed the rationale for Pa'ao's conquest of Hawai'i. Arriving from Ra'iatea (then Havai'i or Havaiki), he found no chiefs eligible to rule. He returned to the South Pacific, recruited Pili Ka'aiea, a prince of the highest bloodlines. With their champions they sailed north and made their conquest, installing Pili Ka'aiea as the progenitor of the dynasty of ruling chiefs from which Kamehameha I was descended 22 generations later.

Activity #6

**Invasive Species Unit 1** 

- 3. Some modern canoe makers who are unaware of its significance omit the distinctive momoa. According to one story, the tradition originated when Mo'ikeha was leaving "Kahiki" (probably the Tahitian island of Ra'iatea) on his return voyage to Hawai'i, and a spirit (*'aumakua*) asked to accompany him. There being no room in the canoe, the spirit said "I will ride upon the small projection I see at the stern end of the hull."
- 4 In old Hawai'i, it was believed that words had a power of their own; prayers or invocations that were not delivered word-perfect would bring no benefit, and might indeed bring harm. The requirement that 'aumakua be addressed in prayer by their names has unhappy implications for Hawaiians who may wish to revive this aspect of their heritage, but who do not know the names of their ancestors or the correct rituals.
- "The gods are dead," an elderly Maori said in a New Zealand Land Court hearing. "But gods cannot die," said the judge.
- "They will die if there is no one who feeds them" said the old man.

#### SUGGESTED READING:

Nānā i ke Kumu, Pūku`i, Haertig, & Lee (Queen Lili'uokalani Children's Center, 1972)

Ka Po'e Kahiko, Kamakau (Bishop Museum Press, 1968)

Prayers by which men and women contacted male or female '*aumakua* were recorded by S.M. Kamakau. Originally published in a Hawaiian language newspaper in 1870, they may be found with translation in Na Pule Kahiko, Gutmanis, (Editions Limited 1983, pp. 16–17). Major spirits (*akua*) are called upon first, then certain '*aumakua*, then the supplicant identifies himself or herself by name and the request is made. Another prayer is found in Nānā i ke Kumu.<sup>6</sup>

Article reprinted courtesy of Hawai'i Division of Aquatic Resources, ©2004