

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*

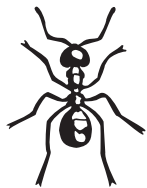
Materials & Setup

- 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. 4-10), “Timeline Cards” (pp. 11, 19-60), “Tables” (pp. 14-17)

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

For Each Student:

- Student Pages “Rate of Introduction” worksheet (pp. 61-62)



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.19-60). Pass one or more cards out to each student and skip to instruction 4.

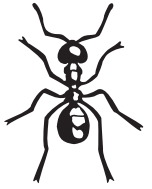
- 2) Assign each group several items from the list included in Teacher Background “Timeline Cards” on page 11. This list includes notable dates in Hawaiian natural history from 30 MA to present. (Find more comprehensive lists on pages 14-17: Teacher Background “Tables 1, 2, and 3.”)
- 3) For each list 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. 61-62) 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 _____

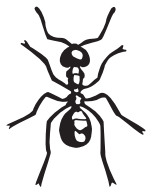
- What did you learn about the history of plant introductions in Hawai‘i?
- How do you think we as humans can limit the rate of introductions to Hawai‘i?
- At what point in the timeline did native species begin to be displaced? At what point were humans negatively impacted?
- Speculate a present outcome 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. 18).]



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, descendants 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.

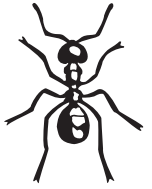
During this century, scientists estimate that new plant species arrive at the rate of about five per year—100,000 times more frequently than in the era before humans arrived in Hawai‘i.

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.

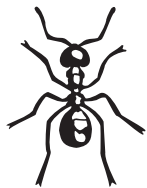
Question: Why do scientists call the Hawaiian monk seal a “living fossil”?

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.

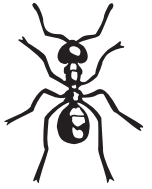
4.7 MA

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 ‘ōhi‘a, one of the keystone species of the native Hawaiian rain forest. A highly variable species, ‘ōhi‘a 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

O‘ahu 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, Moloka‘i, Lāna‘i, 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

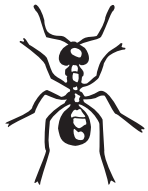
Hawai‘i Island is formed.

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.: 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 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.

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.

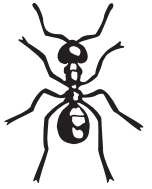
1820: Whalers and missionaries begin arriving.

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: 'ō'ō, *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.

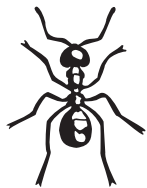
1936: The first commercial flights to Hawai'i begin.

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 *nēnē* goslings, which are brought home to Maui and released in Haleakalā National Park with the help of the Boy Scouts.



Activity #3

Invasive Species Unit 1

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 within 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.

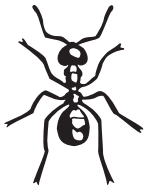
Discovered in 1973, the *po‘ouli* goes extinct. Despite dedicated efforts by conservation agencies to find reproductive birds, the last known individual dies in captivity. The causes of its extinction: habitat loss, avian malaria, and decline in the bird’s primary food source, native Hawaiian tree snails.

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.



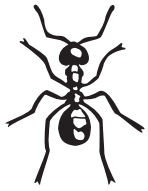
Teacher Background

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 *kūpa ‘oa*.

1. Kure Atoll
2. Fruit fly (Hawaiian *Drosophila* flies) *
3. Bellflower (Hawaiian lobelioids) *
4. Hawaiian monk seal
5. Damselfly (Hawaiian *Megalagrion* damselflies) *
6. Biological Bottleneck
7. Ni‘ihau
8. Eurasian rosefinch (Hawaiian honey-creepers) *
9. California tarweed (Silversword alliance) *
10. Kaua‘i
11. Hawaiian crow
12. *Metrosideros* (‘ōhi‘a species.) *
13. *Moa nalo* (flightless ducks and geese)*
14. O‘ahu
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 0.000333 species were introduced per year.

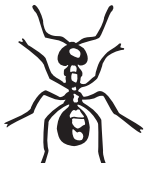
During 1000-1778 AD, the first people of Hawai'i introduced around 30 plants, three mammals, one bird, two reptiles. 36 species/778 years

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

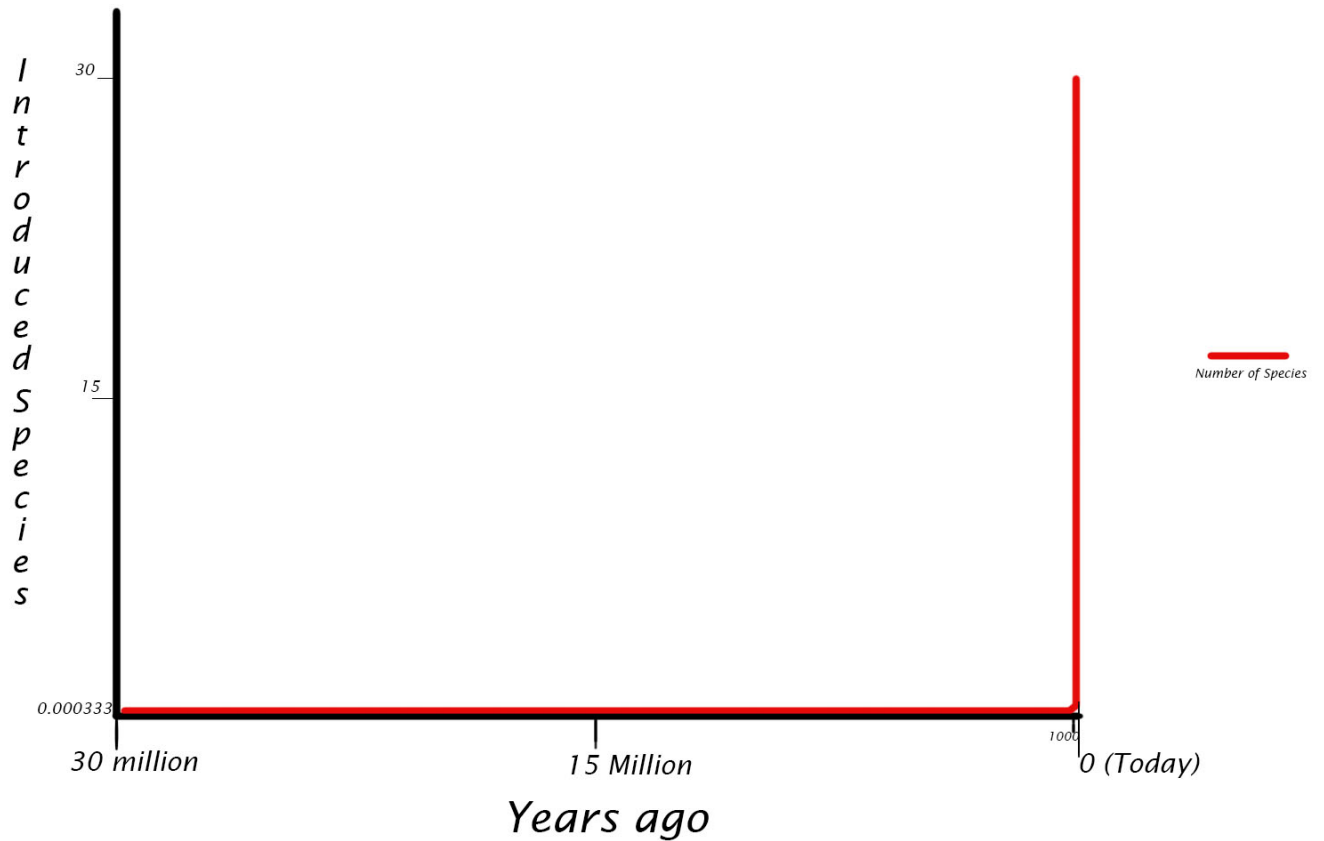
From 1778 to 1840 around one hundred plants were introduced, in addition to numerous animals, insects, and birds. ~100 species/60 years

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

Today 5 plant and 20-40 new insect species are introduced per year.



Rate of Species Introduction in Hawai'i



Extra Credit

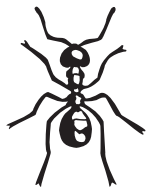
Graph the changes in the human population of Hawai'i.

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 54,000.

Today, the population is 1,428,557 (in 2016).



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

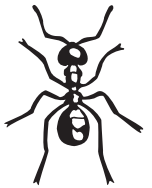


Table 2. Polynesian Introductions

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

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

The Polynesians also introduced animals:
Polynesian pig, Polynesian rat, dog, chicken, skink, gecko

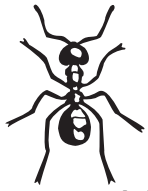


Table 3.

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

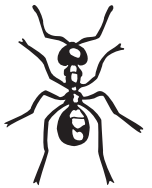
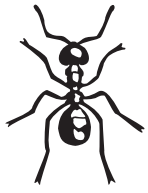


Table 3, continued...

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



Teacher Background

References for Further Research

Polynesian introductions

Cuddihy and Stone, *Alteration of Native Hawaiian Vegetation*, University of Hawai‘i Press, 1990.

Ziegler, *Hawaiian Natural History, Ecology, and Evolution*, University of Hawai‘i 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

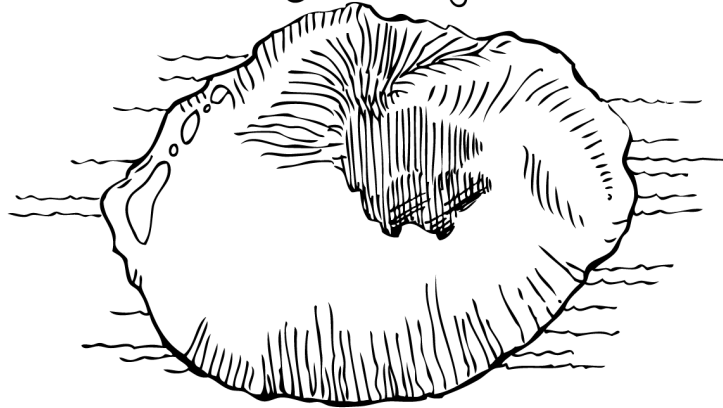
Juvik, Sonia P. and Juvik, James O., *Atlas of Hawai‘i*, Thomas R. Paradise, University of Hawai‘i Press, October 1998.

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.

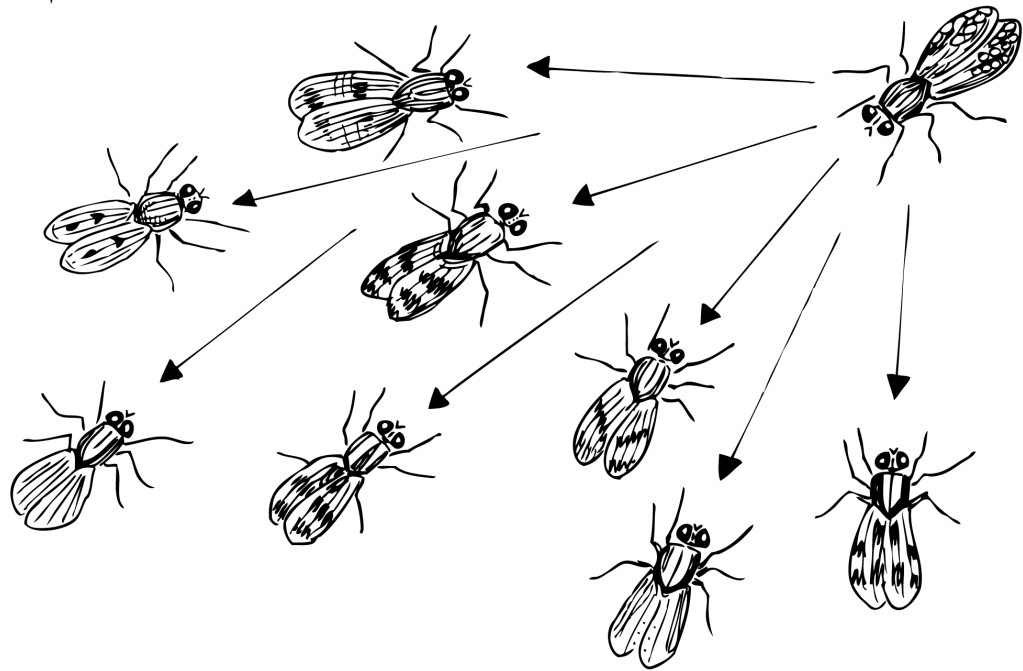


~29.8 million years ago

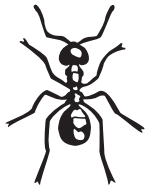


Kure atoll breaks the surface.

~1,000 species 26 Ma.



Hawaiian fruit flies



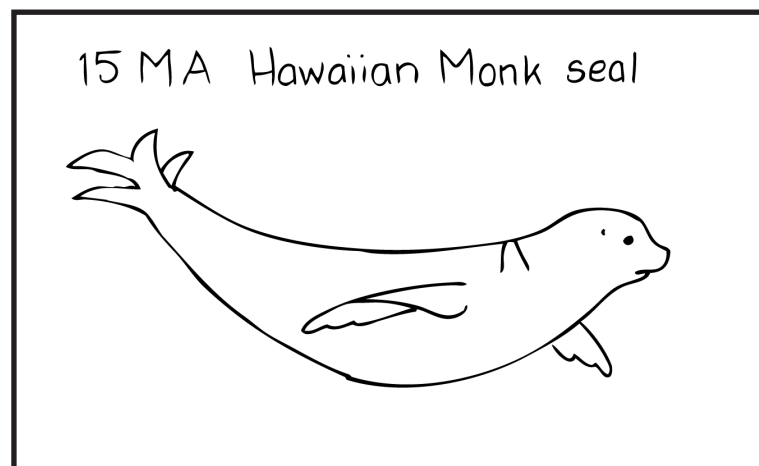
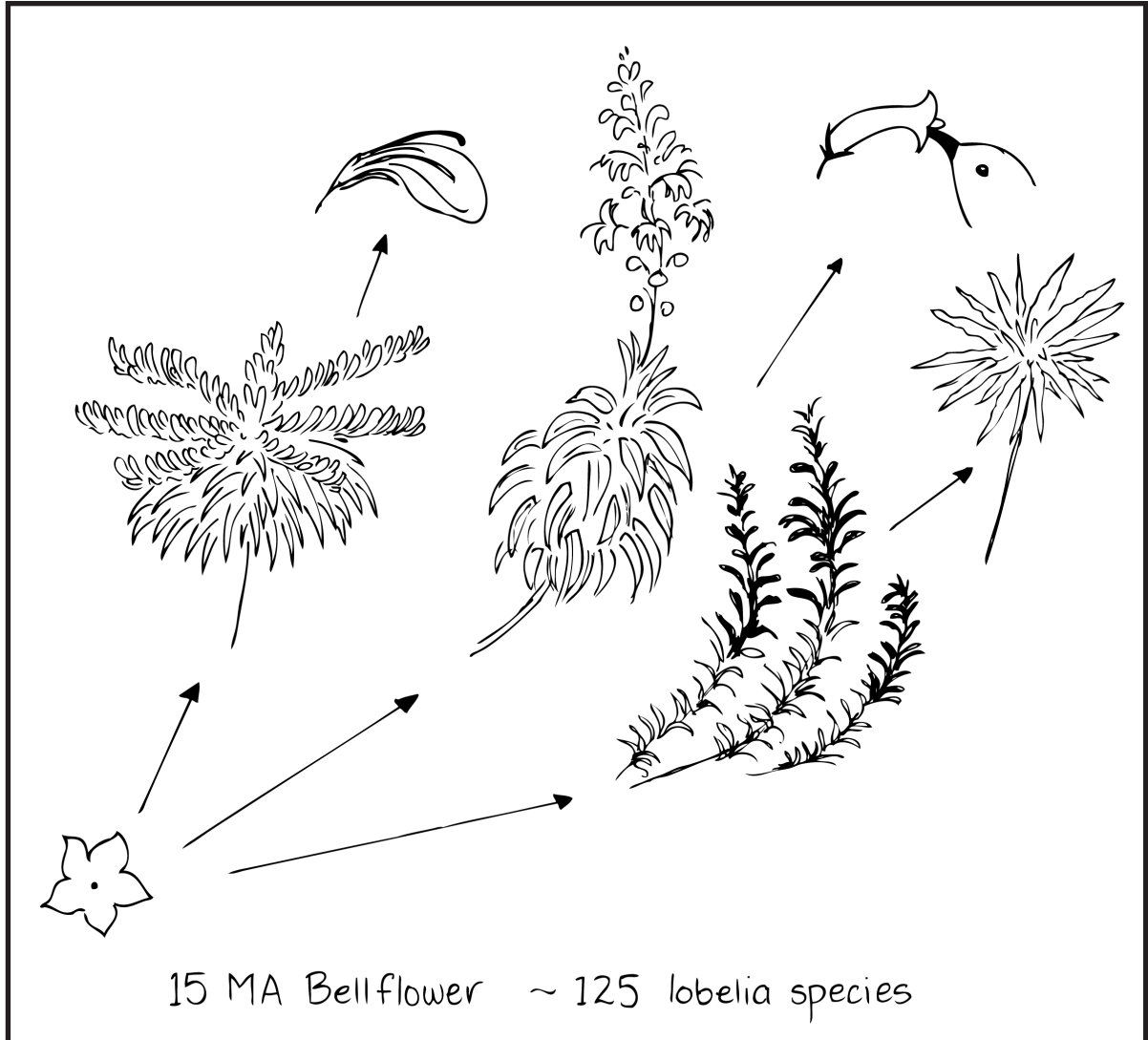
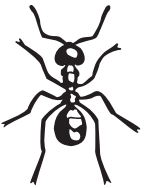
~29.8 million years ago:

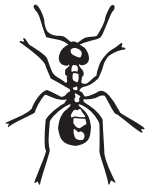
Kure atoll, the oldest existing landmass in the Hawaiian archipelago, breaks the surface of the ocean as a volcanic island.

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

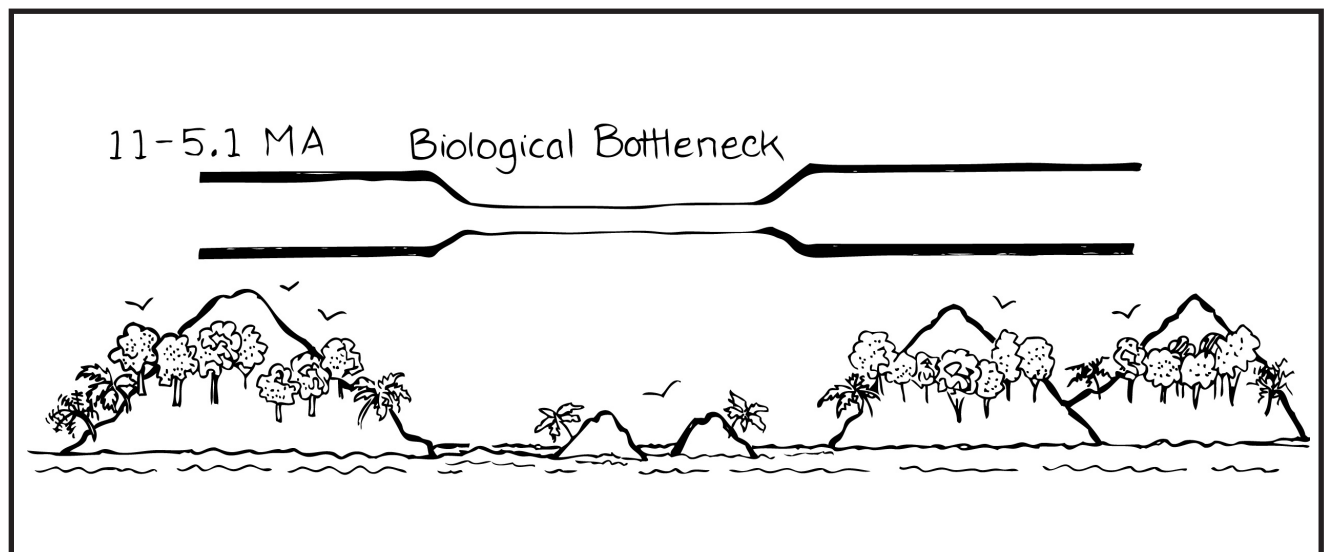
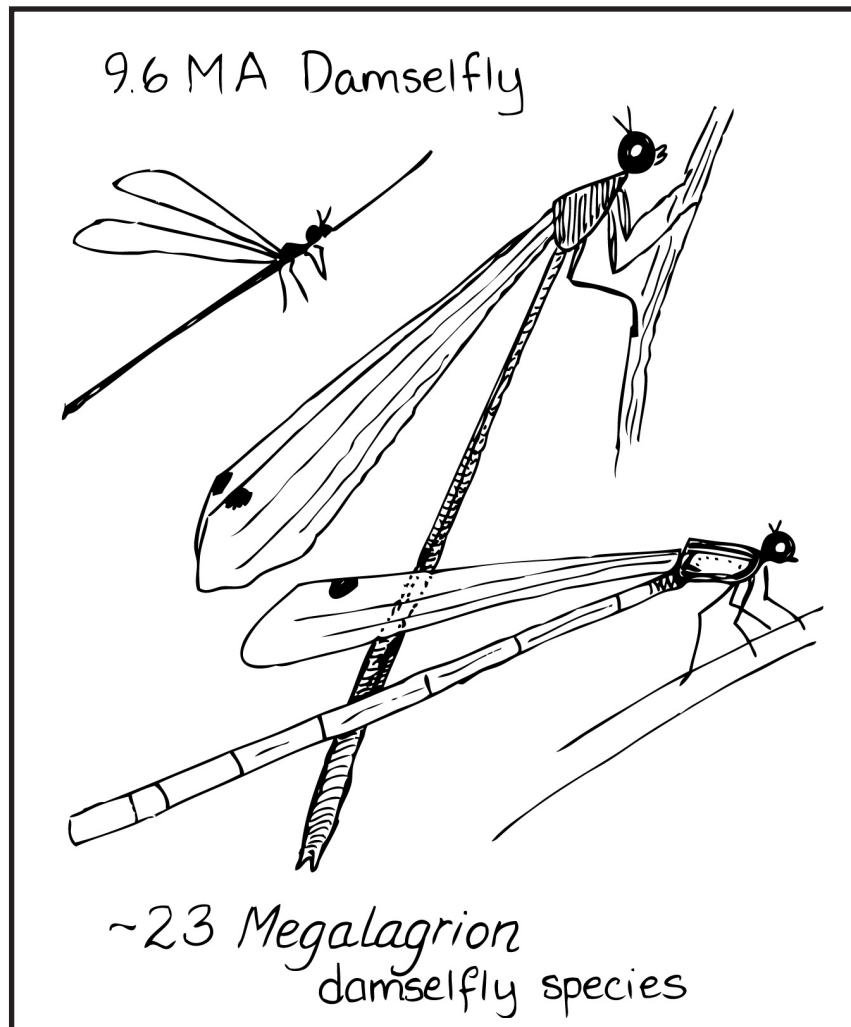
***Bellflower* ~ 125 lobelia species**

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 *‘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.





9.6 million years ago

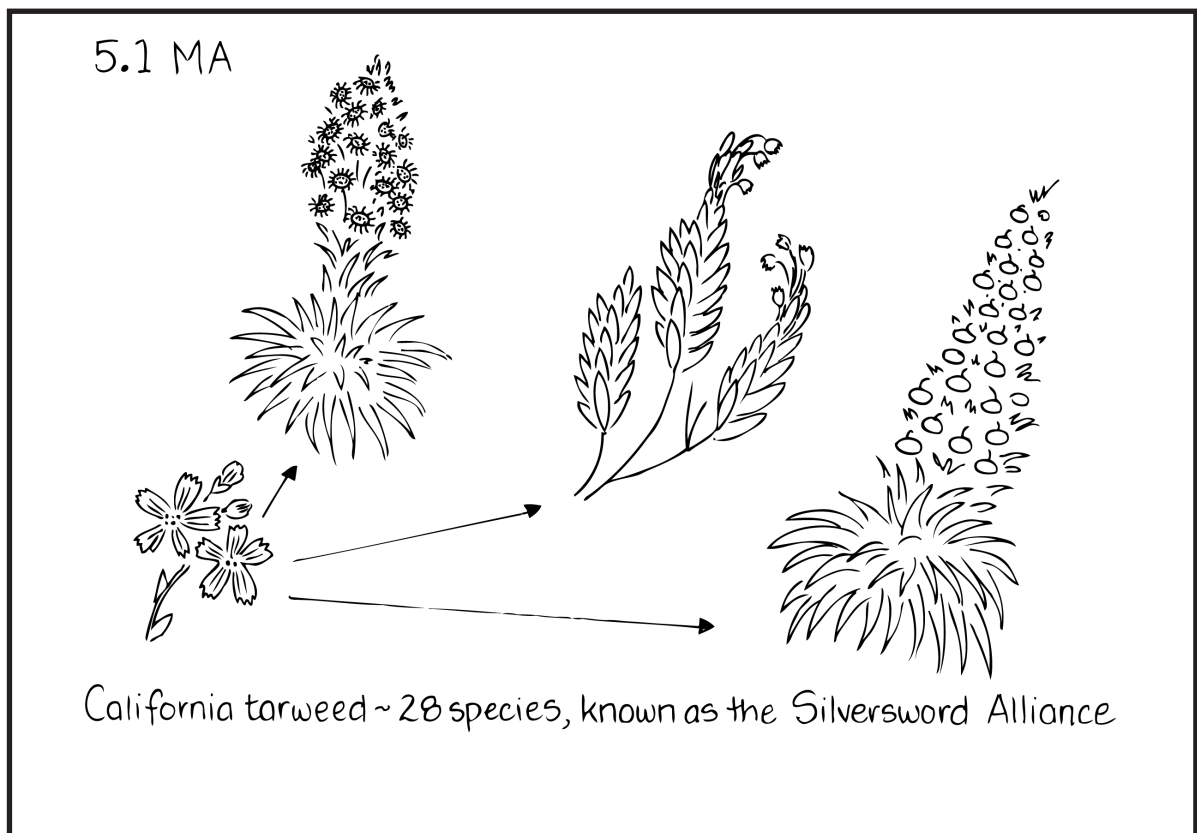
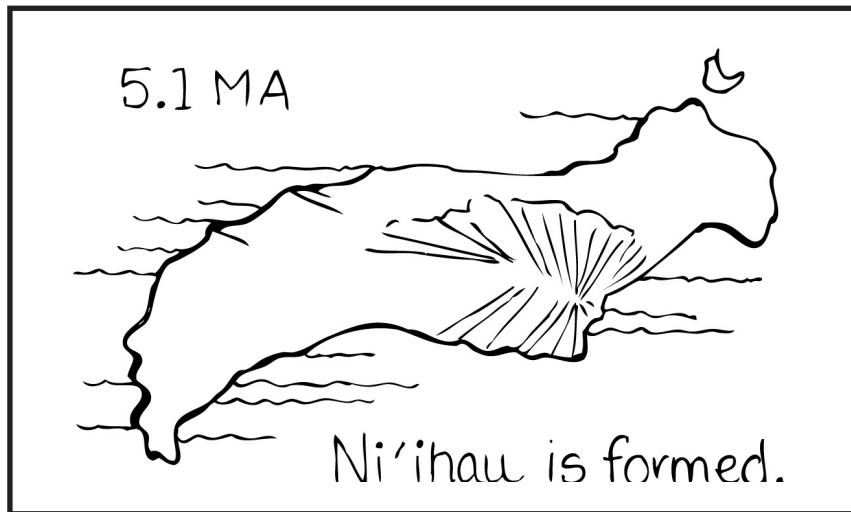
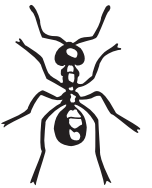
***Damselfly* ~ 23 *Megalagrion* damselfly species**

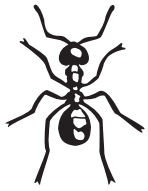
A pioneer damselfly reached the Hawaiian Islands almost ten million years ago. Its ancestors evolved into twenty-three species. These beautiful acrobatic insects come in all colors: bright red, amber, electric blue. Most of the species have aquatic larval stages. Wingless, gilled juveniles hunt along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



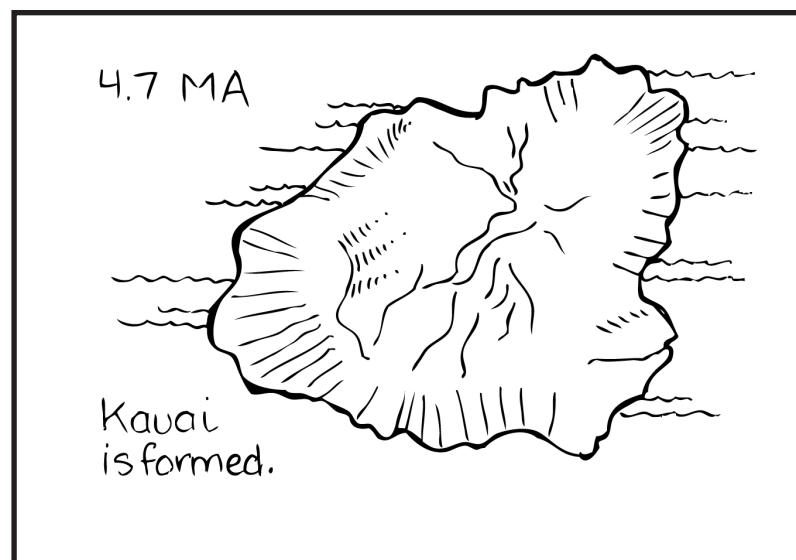
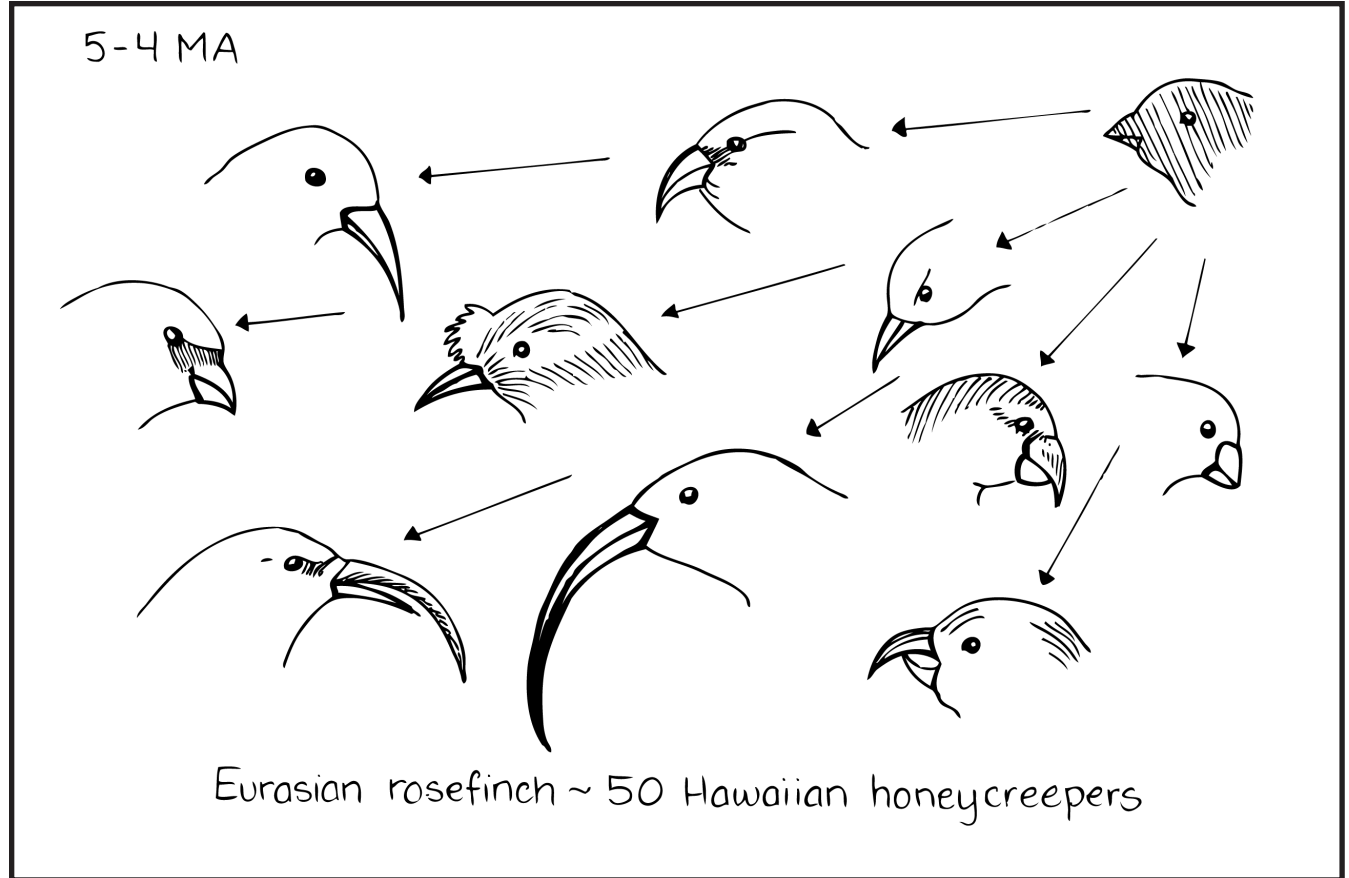
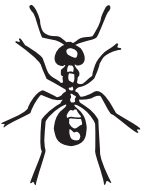


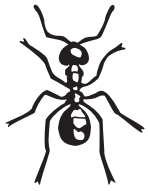
5.1 million years ago
Ni'ihau is formed.

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.





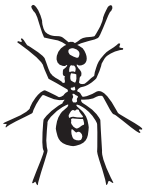
5-4 million years ago

Eurasian rosefinch ~ 50 Hawaiian honeycreepers

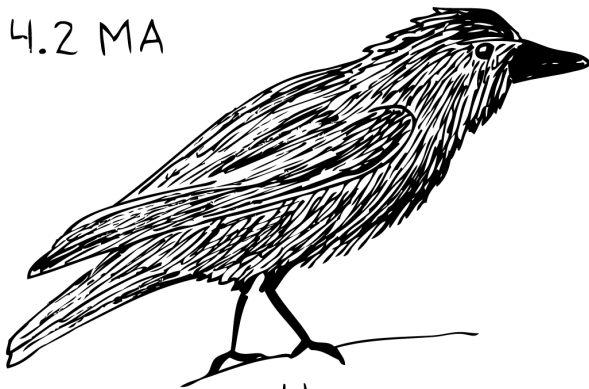
A rather drab finch species is believed to have colonized the Hawaiian Islands between four and five million years ago. From this single **generalist** ancestor, an array of spectacular forest bird species evolves. Each has a **specialized** beak and occupies a unique **niche** in the Hawaiian forest. 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 MA



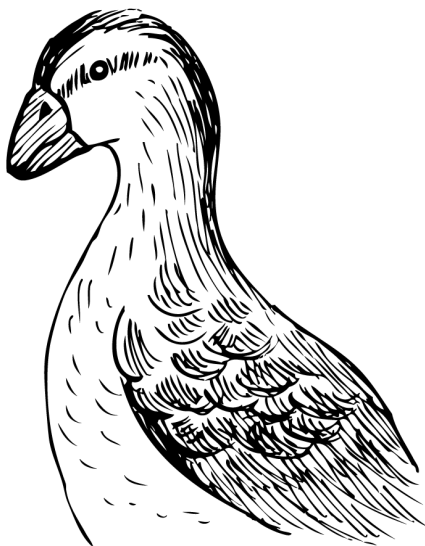
Hawaiian crow

3-4 MA

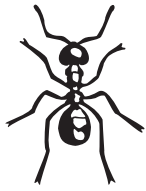


Metrosideros ~ 5 species

3.6 MA



Moa Nalo ~ 4 species
of flightless geese + ducks



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**

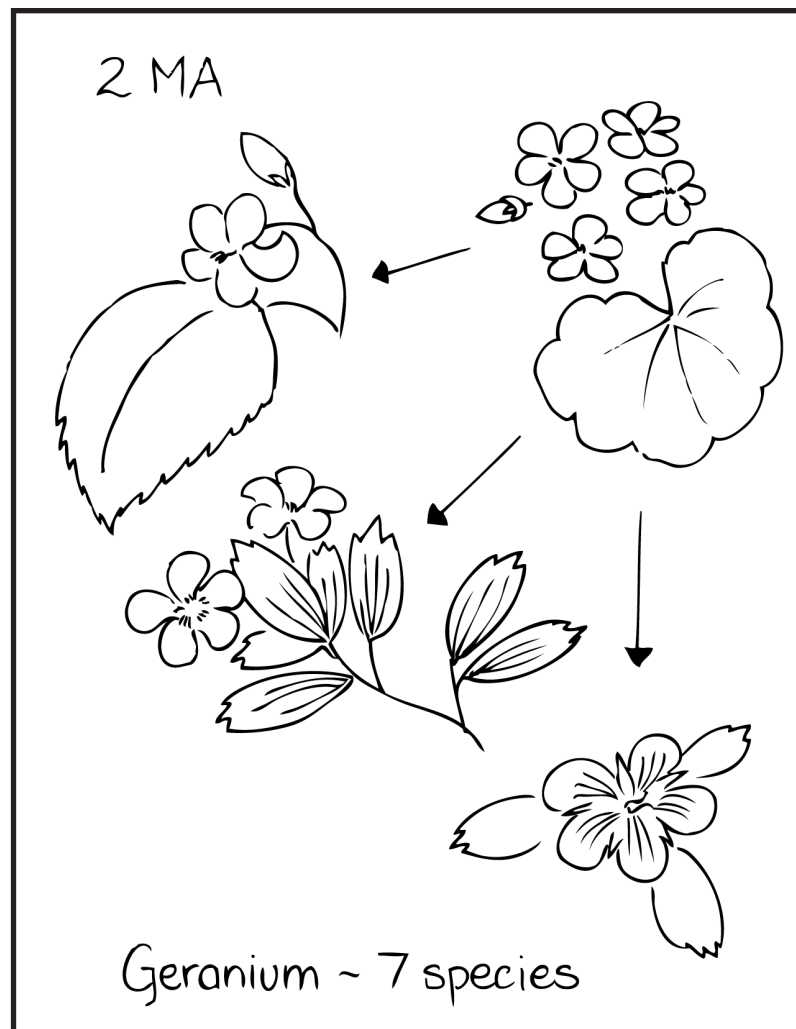
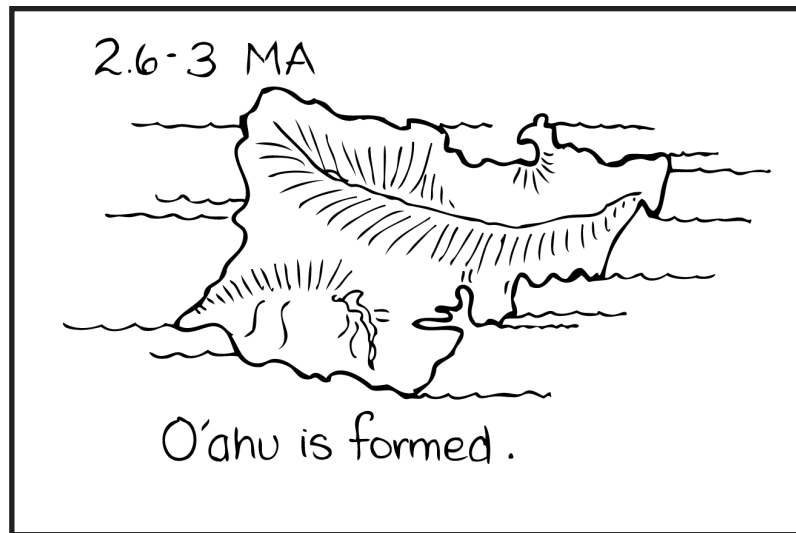
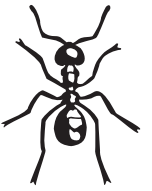
Between three and four million years ago, a plant in the myrtle family successfully took root in the Islands. Its descendants evolved into five species, including 'ōhi'a, one of the keystone species of the native Hawaiian rain forest. A highly variable species, 'ōhi'a grows along the ground as a sprawling 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.

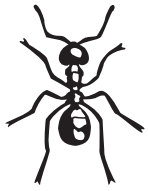
3.6 million years ago

***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.





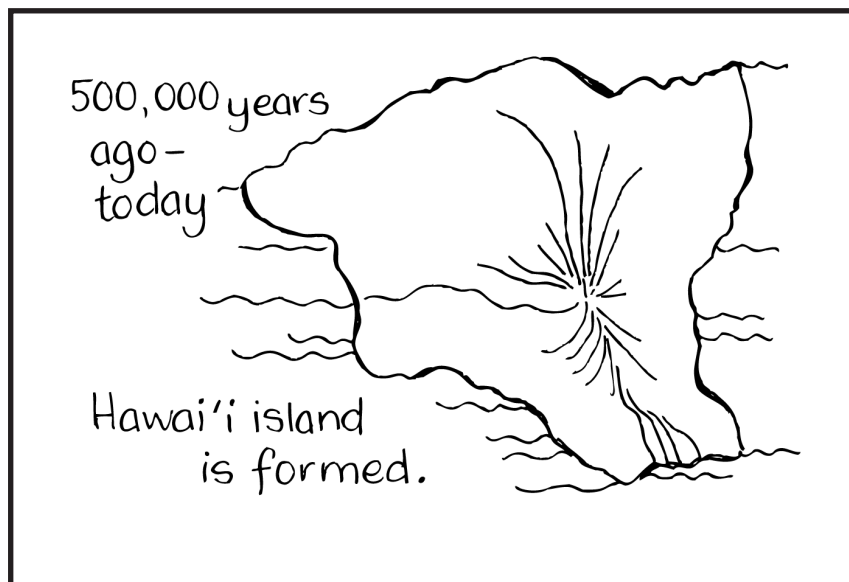
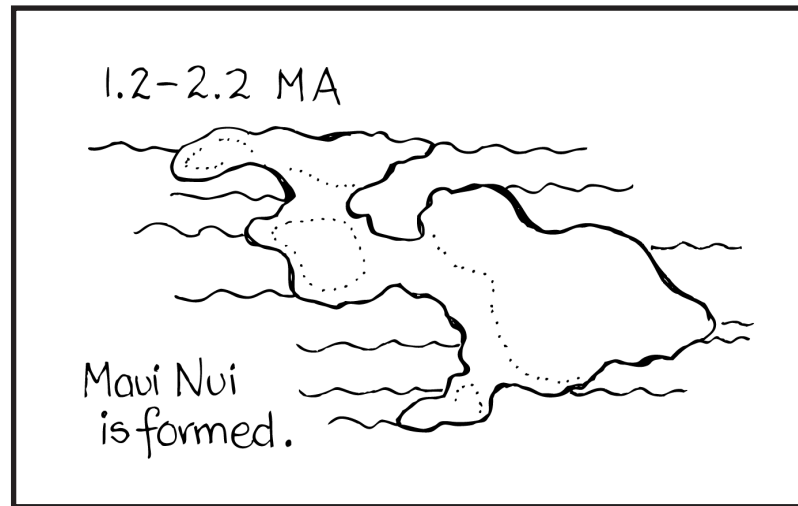
2.6-3 million years ago
O'ahu is formed.

2 million years ago

Nohoanu (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

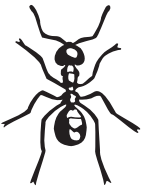
Maui Nui is formed.

The four islands that now make up Maui, Molokaʻi, Lānaʻi, and Kahoʻolawe 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.

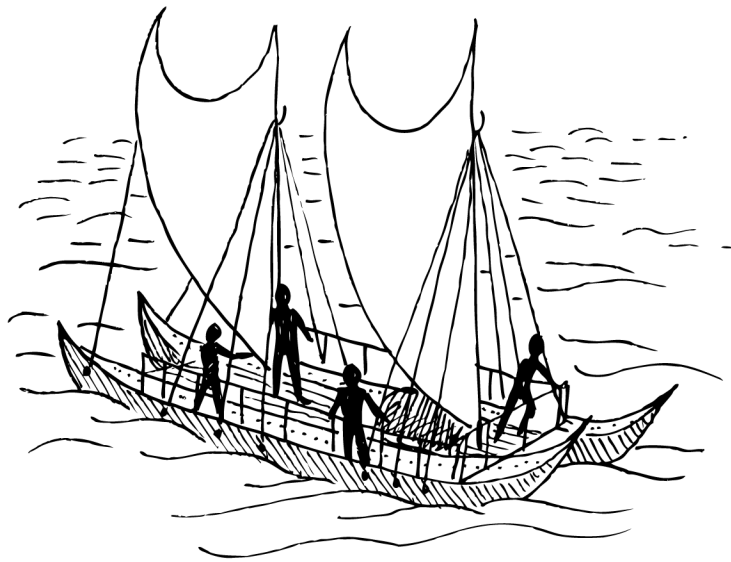
500,000 years ago-today

Hawaiʻi Island is formed.

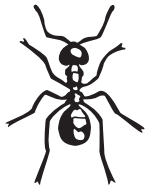
The Island of Hawaiʻi currently sits over the hotspot. (Immediately to its southeast, a new island, Lōʻihi, is forming and has yet to break the surface.)



1000- 1200:



Polynesian voyaging canoes
arrive:
the first humans to colonize
Hawai'i.



1000-1250 A.D.

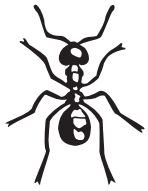
*Polynesian voyaging canoes arrive: the first humans
to colonize Hawai‘i.*



1000-1250:



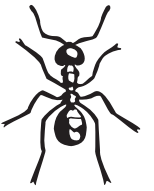
Polynesians introduce
~ 30 plants, 3 mammals, 1 bird and 2 reptiles



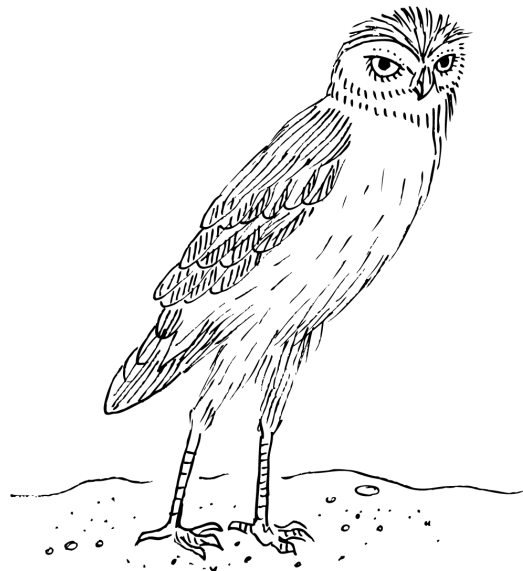
1000-1250 A.D.

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).



1700-1778:

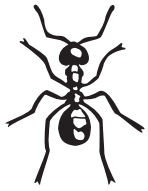


Moa nalo and long-legged
flightless owl go extinct.

1778:



Captain Cook brings plants to outfit his ship on its return...
and the European boar.



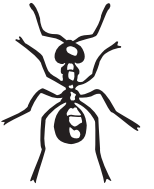
1100-1778

Moa nalo and long-legged flightless owl go extinct.

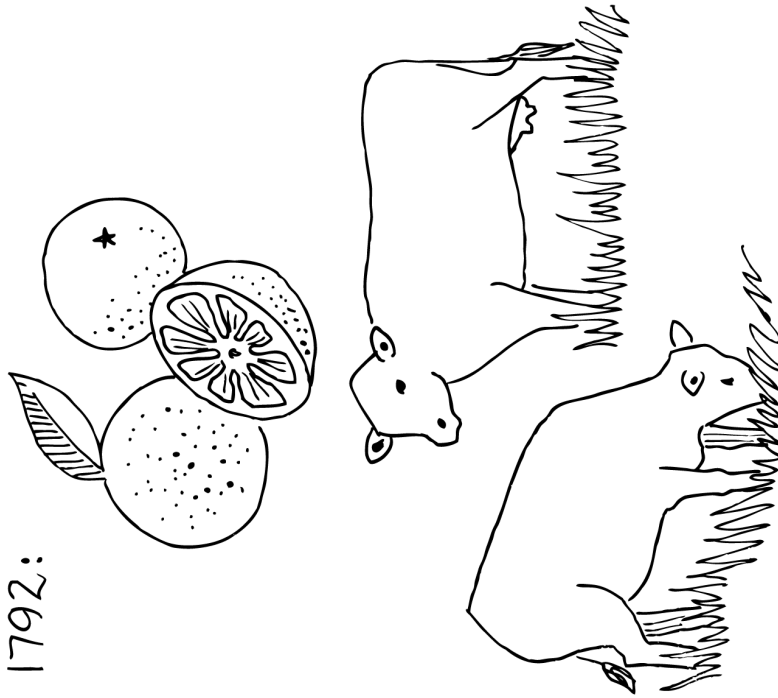
Predation by rats and humans causes numerous flightless birds go extinct during this period. Flightless birds build their nests on the ground and have no protection from introduced predators.

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.

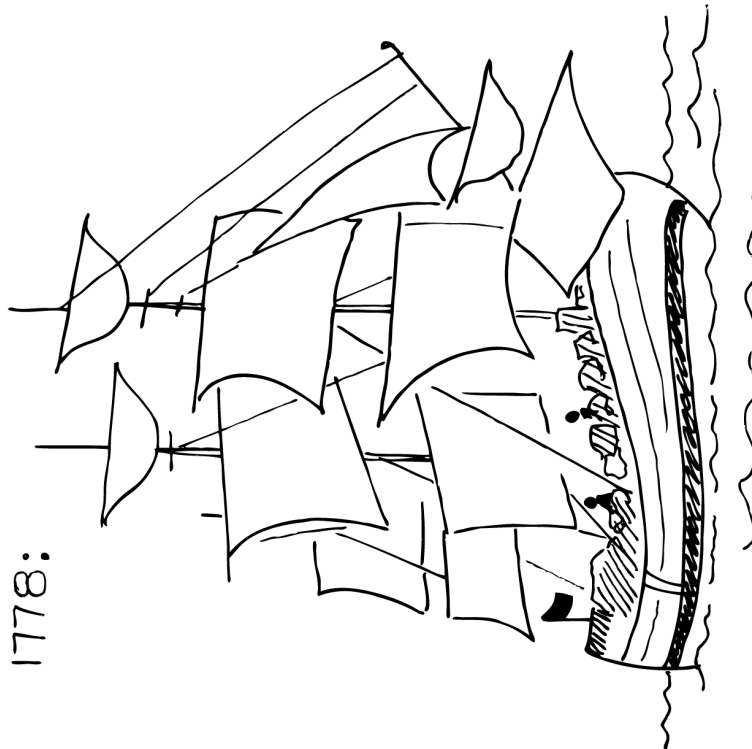


1792:



Captain Vancouver brings oranges
and gives King Kamehameha
several head of cattle.

1778:



The first Europeans
arrive in Hawai'i.



1792

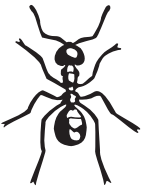
Captain Vancouver

Captain Vancouver brings oranges and gives King Kamehameha several head of cattle.

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 boat.

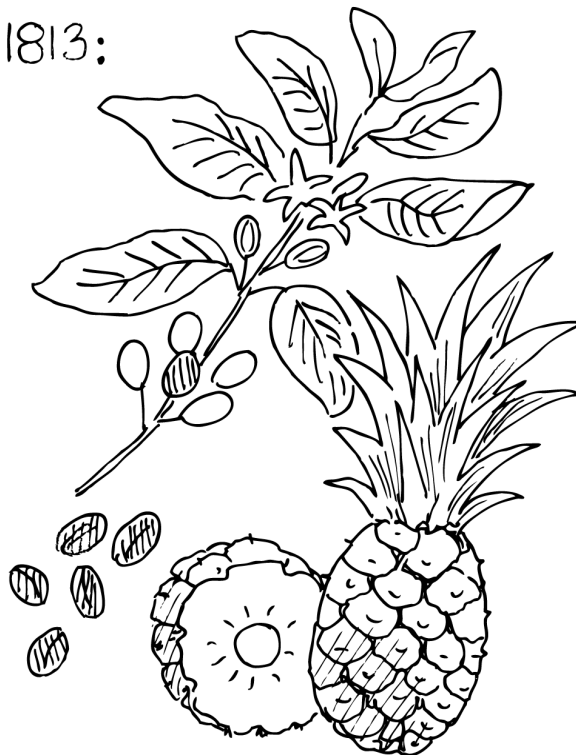


1804:



Chinese sandalwood trade begins.

1813:



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



1804

Chinese sandalwood trade begins.

Western fur traders discover dollar signs in the forest:

Hawaiian sandalwood or ‘iliahi, 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

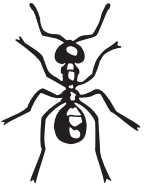
I trades shiploads of sandalwood logs for Western weapons and boats. Overwhelmed by debt, his successor, Kamehameha II, requires men, women, and children to cut and carry sandalwood from the forest.

Farmers are forced to leave their *lo ‘i* (taro patches), fishermen their fishponds to gather sandalwood.

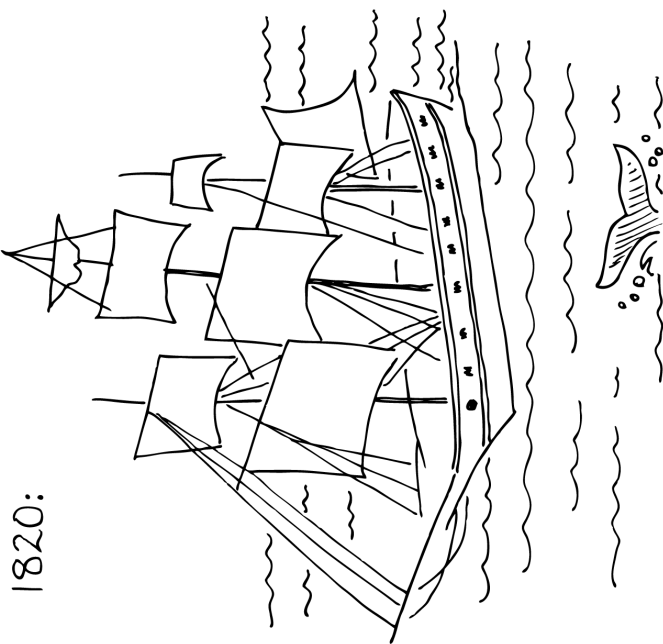
Famine ensues.

1813

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



1820:



Whalers and missionaries
begin arriving.

1826-
present:

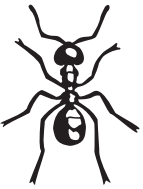


Hawaiian forest birds
go extinct.

1826:



Sailors from the whaling ship
Wellington dump mosquito larvae
into Lahaina canals.



1826-present

Forest birds go extinct.

Many Hawaiian forest birds (eg: 'ō'ō, *mamo*,
'*akiāloa*) succumb to **avian malaria** and
habitat loss.

1820

Whalers and missionaries begin arriving.

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.

[illegible]

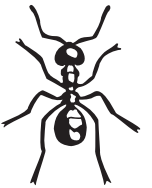
From Evolution in Isolation to Globalization - **Hō'ike o Haleakalā**



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.

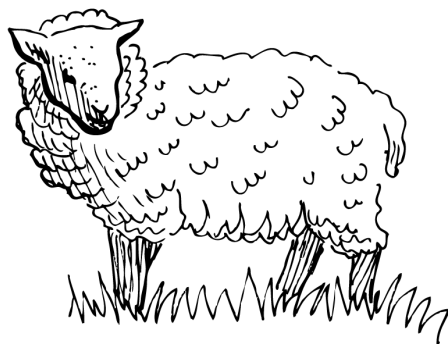


1840:

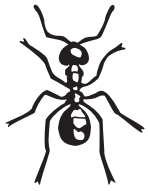
Sandalwood trade collapses
due to over-harvesting.



1840:



Sheep arrive in Hawai'i.



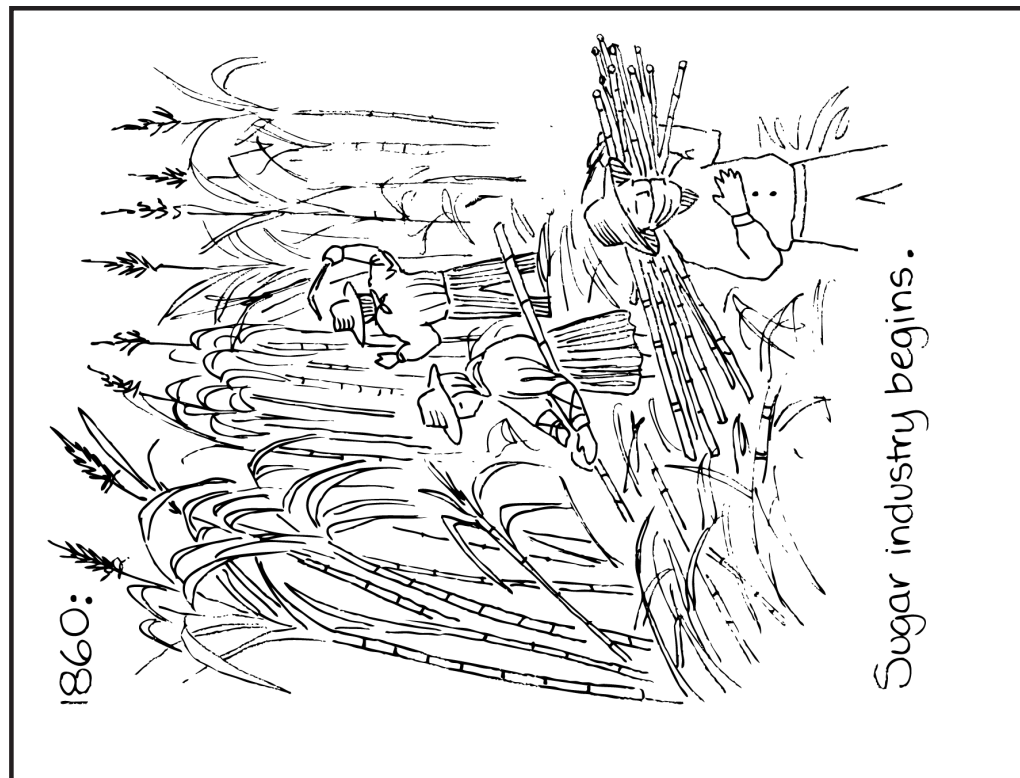
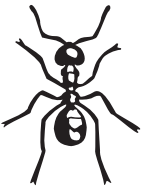
1840

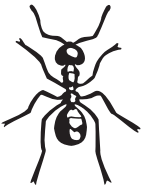
Sandalwood trade collapses due to over-harvesting.

1840

Sheep arrive in Hawai‘i.

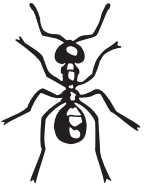
Able to scale cliffs, feral sheep access the remaining **pristine** forest areas. They devastate populations of native lobelias, hibiscus, and other rare plants.



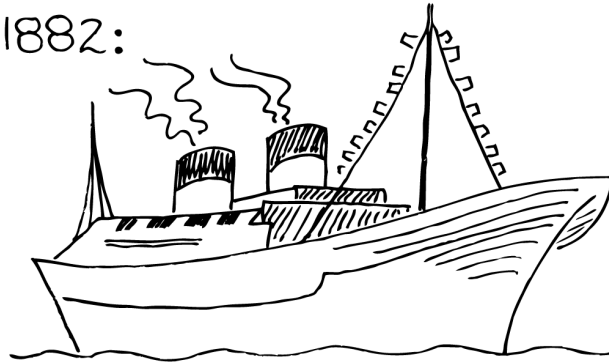


1870
Eucalyptus widely planted on Maui.

1860
Sugar industry
As whaling declines, the sugar industry thrives;
workers from China and Japan are brought in to
work the fields.



1882:

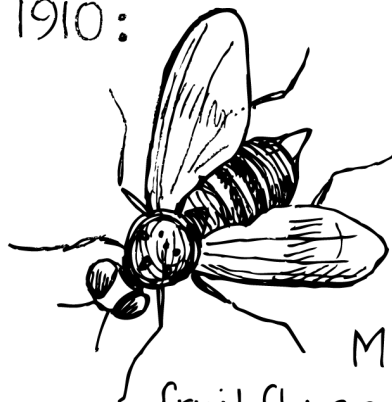


Matson Lines begins overseas shipping operations.

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



1910:



Mediterranean
fruit fly arrives in Hawai'i.



1882

Matson Lines begins overseas shipping operations.

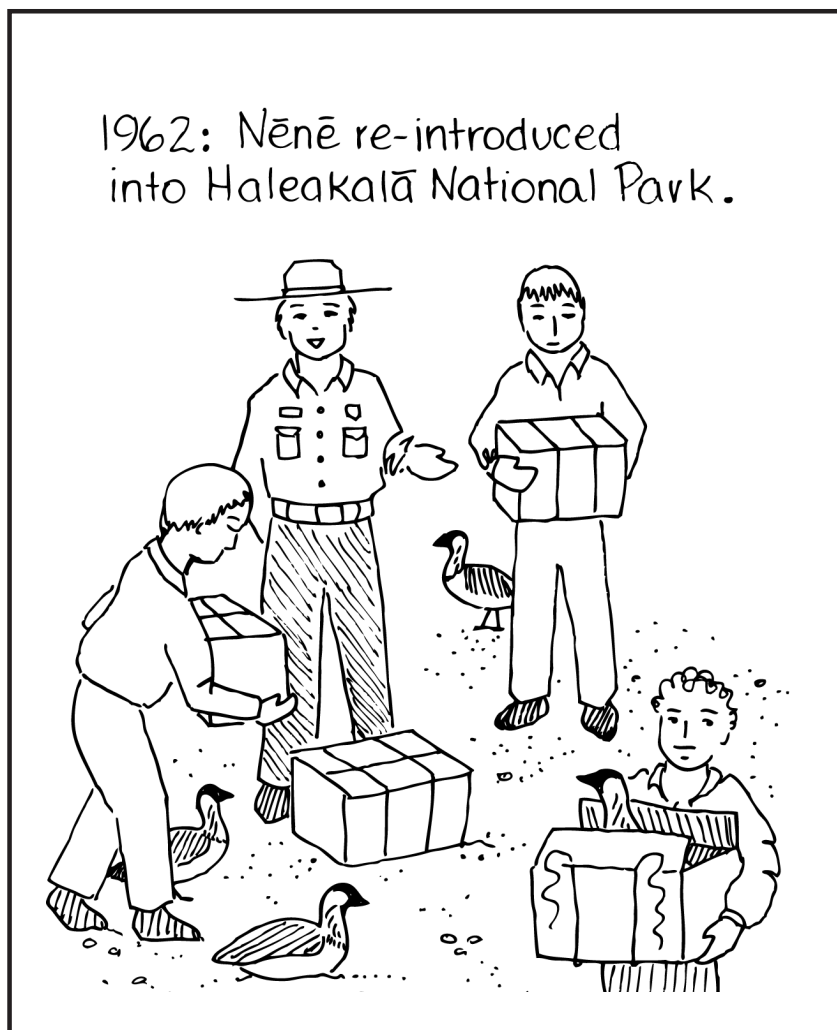
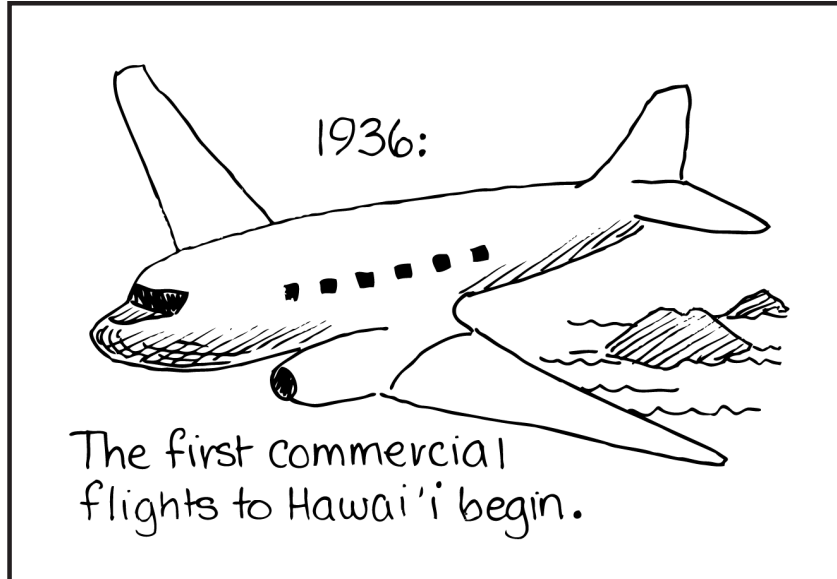
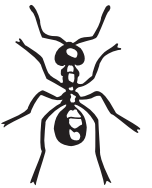
1890

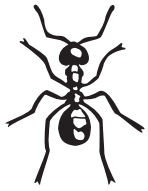
Nēnē, the Hawaiian goose, disappears from Maui.

Introduced cats, rats, and mongoose 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.





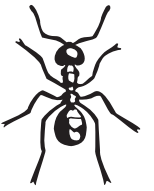
1936

The first commercial flights to Hawai'i begin.

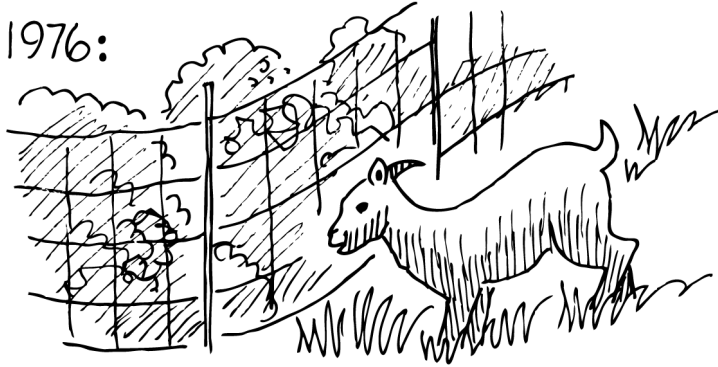
1962

Nēnē re-introduced into Haleakalā National Park.

A captive breeding program in England successfully raises *nēnē* goslings, which are brought home to Maui and released in Haleakalā National Park with the help of the Boy Scouts.

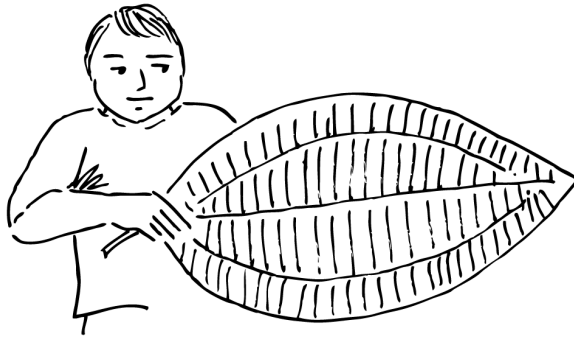


1976:



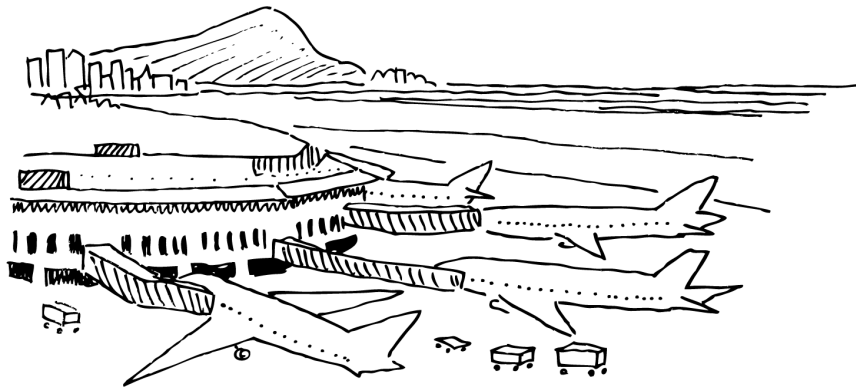
Fencing of Haleakalā National
Park boundary begins.

1991:



The Melastome Action
Committee forms.

1994: Honolulu ranked as fifteenth
busiest airport in the U.S.,



handling 22.9 million passengers
per year.



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 within the park. This work continues today.

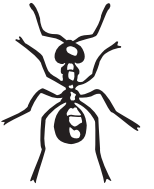
1991

The Melastome Action Committee forms.

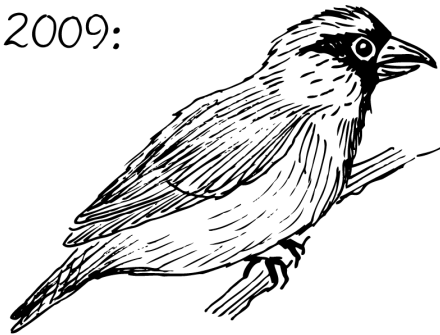
Conservationists from several agencies band together to stop the invasion of highly aggressive plants in the melastome family, including *Miconia calvescens*. Ultimately this results in the creation of the Invasive Species Committees on each island, tasked with preventing the introduction and spread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

1994

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



2009:

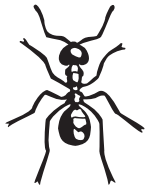


Po'ouli goes extinct.

Ongoing:
Conservation agencies
work to preserve intact native
Hawaiian ecosystems and
prevent the introduction of
new species.

**HAWAI'I
CONSERVATION
CONFERENCE**





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,

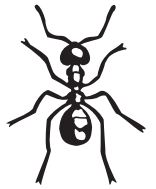
West Maui Mountains Watershed Partnership,

Leeward Haleakalā Watershed Partnership,

Lanai Forest & Watershed Partnership,

East Molokai Watershed Partnership,

among others.)



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.

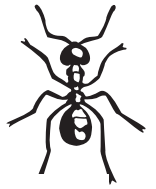
During 1000-1778 AD, the first people of Hawai'i introduced around 30 plants, three mammals, one bird, two reptiles. 36 species/778 years.

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

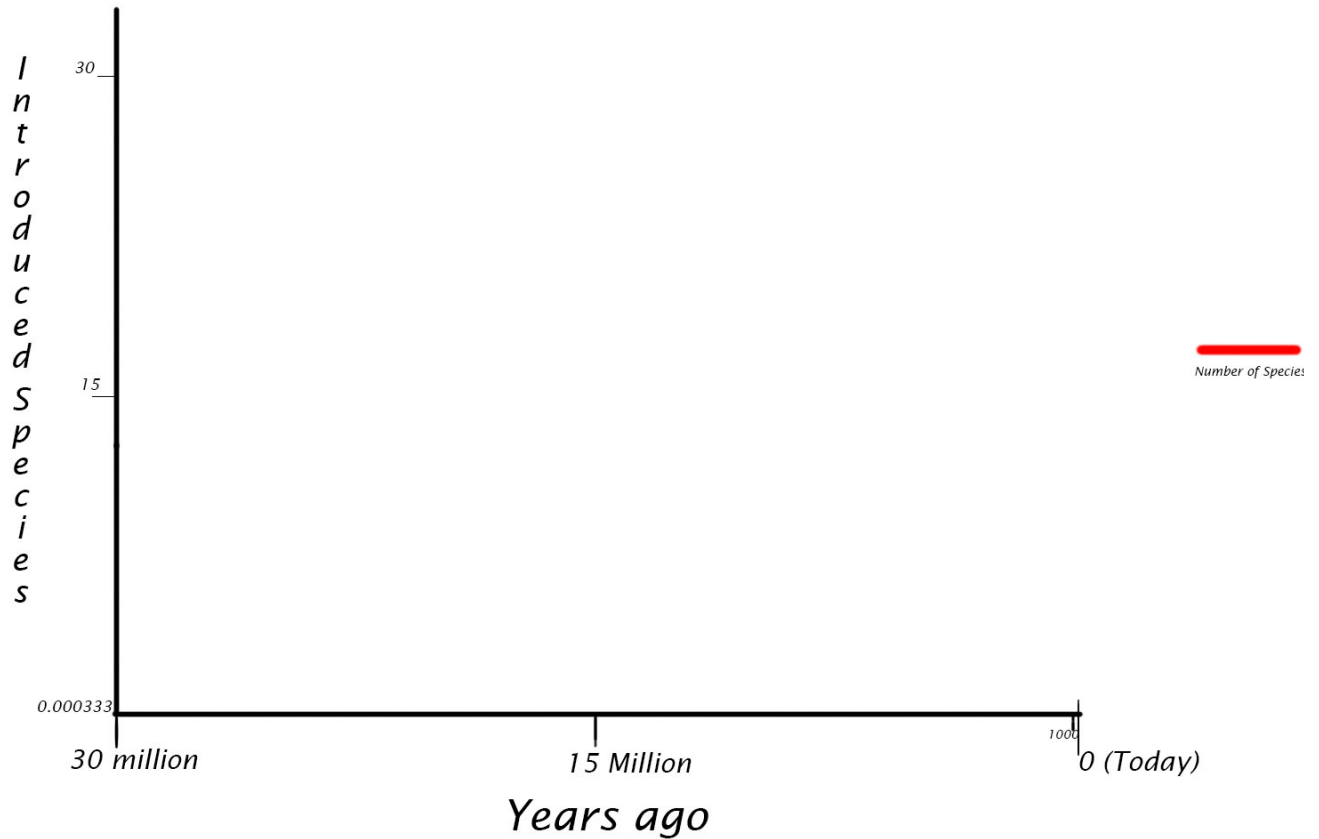
From 1778 to 1840 around one hundred plants were introduced, in addition to numerous animals, insects, and birds. ~100 species/60 years.

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

Today _____ species are introduced per year.



Rate of Species Introduction in Hawai'i



Extra Credit

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

Prior to 1000 AD, the population was _____.

In 1778 AD, the estimated population was _____.

In 1886 AD, the estimated population was _____.

Today, the population is _____.