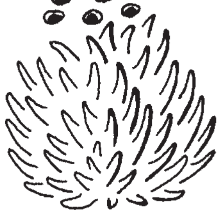



Rain Forest Unit 3

Rain Forest Birds: A Study in Adaptation

Overview

Between the native species living today and the fossil record still being unearthed, there is plenty of evidence for the remarkable diversity of bird life that evolved on the Hawaiian Islands. By looking at rain forest birds, students explore how that diversity of life may have evolved, including the process of adaptive radiation. They also learn about the effects of human pressure on species survival and ongoing threats to native bird species, and they conduct independent research projects on native rain forest birds.

Length of Entire Unit

Three class periods, plus optional research and presentation time

Unit Focus Questions

1) What is adaptive radiation and how has this process influenced the evolution of species in Hawaiian rain forests?

2) What are historic and current threats to native rain forest bird species?

Unit at a Glance

Activity #1

Win, Lose, or Adapt Game

Students play a game to develop a basic understanding of the process of adaptive radiation, the effects of habitat loss and competition for food, and the concepts of feeding "specialists" and "generalists."

Length
One class period followed by homework

Prerequisite Activity
None

Objectives
- Evaluate and describe the effects of habitat loss and competition for food on native birds.
- Apply the concepts of "specialization" and "generalization" to discuss species survival under changing conditions.
- Hypothesize about the comparisons between the simulated adaptive radiation in the game and evolution in nature.

DOE Grades 9-12 Science Standards and Benchmarks
USING UNIFYING CONCEPTS AND THEMES: Students use concepts and themes such as system, change, scale, and model to help them understand and explain the natural world.
- CHANGE: Explain the effects of large and small disturbances on systems in the natural world.

BIOLOGICAL EVOLUTION: Students examine evidence for the evolution of life on earth and assess the arguments for natural selection as a scientific explanation of biological evolution.
- Explain the basic idea behind biological evolution.

Activity #2

Adaptive Radiation in Rain Forest Birds

Through a homework reading, questions, and class discussion, students learn about adaptive radiation in Hawaiian honeycreepers.

Length
One class period, preceded by homework

Prerequisite Activity
None

Objectives
- Define and adaptive radiation.
- Describe factors that are thought to have influenced adaptive radiation among Hawaiian honeycreepers.

DOE Grades 9-12 Science Standards and Benchmarks
USING UNIFYING CONCEPTS AND THEMES: Students use concepts and themes such as system, change, scale, and model to help them understand and explain the natural world.
- CHANGE: Explain the effects of large and small disturbances on systems in the natural world.

BIOLOGICAL EVOLUTION: Students examine evidence for the evolution of life on earth and assess the arguments for natural selection as a scientific explanation of biological evolution.
- Explain the basic idea behind biological evolution.

Activity #3
Rain Forest Birds Research Projects

Students select a topic related to native Haleakalā rain forest birds and conduct an independent research project on that topic.

Length
One class period, plus optional class time for research and presentations

Prerequisite Activity
None

Objectives
- Research and report on one topic related to native birds of the rain forest on Haleakalā.

DOE Grades 9-12 Science Standards and Benchmarks
LIVING THE VALUES, ATTITUDES, AND COMMITMENTS OF THE INQUIRING MIND: Students apply the values, attitudes, and commitments characteristic of an inquiring mind.
- QUESTIONING: Ask questions to clarify or validate purpose, perspective, assumptions, interpretations, and implications of a problem, situation, or solution.
- SELF-DIRECTED: Use research techniques and a variety of resources to complete a report on a project of one's choice.

Enrichment Ideas

- Research and accurately color line drawings of native rain forest birds. Use the *Forest Jewels of Hawai'i* coloring book (Hawai'i Department of Land and Natural Resources, Division of Forestry and Wildlife, Honolulu, 1996) along with the images of birds in Arthur C. Medeiros, and Lloyd L. Loope, *Rare Animals and Plants of Haleakalā National Park*, Hawai'i Natural History Association, Hawai'i National Park, Hawai'i, 1994.

- Produce original drawings, watercolor or oil paintings, or other artistic and accurate representations of Hawaiian rain forest birds.

- Design a bird to fit different types of food sources. Collect samples or drawings of potential food sources for birds and draw or construct a model of a bird head and beak (or an entire bird) that is adapted to the food source(s). Potential food sources:
  - Flowers of different sizes and shapes,
  - Seeds and nuts of different sizes and shapes,
  - Tree branches or trunks with different types of bark (look for variations such as smooth surfaces on which insects crawl, crevices that shelter insects, or different thicknesses of bark that birds would peel or pry off to reach larvae burrowed underneath),
  - Fruits of various sizes, shapes, and textures, and
  - Insects of different sizes and shapes that have different life histories (e.g., larval stages that burrow in leaf buds, roots, or woody plant stems).

- Make research presentations (Activity #3) to the rest of the class.

Resources for Further Reading and Research

Carlquist, Sherwin, *Hawaii: A Natural History*, Pacific Tropical Botanical Garden, Lawai, Kauai, Hawai‘i, 1980.

Chapter 11, “The Honeycreepers and Other Birds,” includes many photographs and line drawings of honeycreepers along with notations about their food sources.

Freed, L. A., S. Conant, and R. C. Fleisher, “Evolutionary Ecology and Radiation of Hawaiian Passerine Birds,” in Kay, E. A. (ed.), *A Natural History of the Hawaiian Islands, Selected Readings II*, University of Hawai‘i Press. Honolulu, 1994, pp. 335-345.

Givnish, T. J., K. J. Sytsma, J. F. Smith, and W. J. Hahn, “Molecular Evolution, Adaptive Radiation, and Geographic Speciation in *Cyanea (Campanulaceae, Lobelioideae)*,” in Wagner, W. L., and V. A. Funk (eds.), *Hawaiian Biogeography: Evolution on a Hot Spot Archipelago*, Smithsonian Institution, Washington, DC, 1995, pp. 288-337.

Juvik, James O., “Biogeography,” in Juvik, Sonia P., and James O. Juvik (eds), *The Atlas of Hawai‘i*, 3rd ed., University of Hawai‘i Press, Honolulu, 1998, pp. 103-106.

Medeiros, Arthur C., and Lloyd L. Loope, *Rare Animals and Plants of Haleakala National Park*, Hawai‘i Natural History Association, Hawai‘i National Park, Hawai‘i, 1994.

Smith, T. B., L. A. Freed, J. K. Lepson, and J. H. Carothers, “Evolutionary Consequences of Extinctions in Populations of a Hawaiian Honeycreeper,” *Conservation Biology*, Vol. 9, No. 1, 1995, pp. 107-113.

Activity #1

Win, Lose, or Adapt Game

● ● ● **Class Period One** *Win, Lose, or Adapt Game*

Materials & Setup

- "Food Competition Action Chart," for your reference (master, p. 12)
- "Scenario Cards" (master, pp. 13-16)

For each student

- Student Page "Win, Lose, or Adapt: Questions About the Game" (pp. 17-18)

For each group of six to eight students

- Two decks of playing cards
- "Game Instructions" (master, p. 9)
- "Beak-Type Wheel" (master, p. 10)
- "Bird/Player Identification Cards"—Eight each of four beak types (master, p. 11)
- "Food Competition Action Chart," one copy (master, p. 12)

Instructions

1) Divide the class into groups of six to eight students, and give each group the materials listed above.

2) You are the "master of ceremonies" for this game, making sure players understand and follow instructions and reading the "Scenario Card" that precedes each round of competition. Begin the game by reviewing the "Game Instructions" with students. Make sure that everyone understands that they are looking for any three-of-a-kind, regardless of suit.

3) Begin each round by reading the appropriate "Scenario Card." End each round by asking groups to tally the number of food items each player collected and following the instructions on the "Food Competition Action Chart."

4) Use the question on the final "Scenario Card" to begin a class discussion about the game and its results. Other discussion questions include:
   - Which kind of bird was most successful? Why?
   - What does this game tell us about adaptation and evolution in the natural world?
   - How many honeycreeper species do you think actually evolved in the islands?

   If you are continuing with Activity #2, students will be able to answer these questions better, based on their homework reading.

5) Assign the Student Page "Win, Lose, or Adapt: Questions About the Game" as homework (or discuss in class).

Assessment Tools

- Student participation in the game.
- Student Page “Win, Lose, or Adapt: Questions About the Game” (teacher version, pp. 7-8)

Teacher Version

Win, Lose, or Adapt: Questions About the Game

1) In the game, the "jacks" had to get three of a kind of any card, while the specialized birds only had to get a pair but in a certain numeric range. How do you think this division of food items parallels what happens in nature?

   Well-reasoned responses are acceptable. The specialized birds have a limited range of food items and are well-adapted for that kind of food. The "jacks" have a wider range of food sources, but they may have lower feeding efficiency than the specialists for each one, making it slightly more difficult for them to obtain food from particular sources.

2) What effect do you think declining food sources would have on overall population size of native birds? Why? What would you need to know in order to predict the effects on different types of birds (i.e., nectar sippers, etc.)?

   Any well-reasoned response is acceptable. The basic line of reasoning is likely to be that declining food sources would support a smaller number of birds. In order to gauge the effects on the different types of birds, one would probably need to know how different types of habitat were changing, whether a species of plant that bird is dependent on is declining, whether the birds have substitute food sources in other habitats, etc.

3) If all food sources are declining equally rapidly, which of the four types of birds do you think would have the advantage? Why?

The likely response is the jacks, because they can exploit all food sources and would likely be able to shift between food sources, depending on what's available. (Again, any well reasoned response is acceptable.)

4) List and explain at least two ways in which you think this game is similar to/different from the actual process of evolution and adaptation.

Well-reasoned responses are acceptable. Examples of responses include:

- In the game, the direction of evolution in beak shape/food specialization is determined by a chance roll of the die. In nature, environmental conditions and genetic characteristics determine the direction of natural selection.
- In the game, populations of the most successful species increased without evolving. This probably is the case most often in nature as there is less selective pressure on successful species.
- In the game, it may seem as though adaptation and evolution are happening to individual birds, when in reality the process takes place over many, many generations and entire species.
- In the game, we lumped all nectar eaters together into one group and did the same with the other types of birds. In reality, bird species can be even more specialized to specific sources of food, and changes in the abundance and type of food sources will create selective pressures that are different among species that fall into the same general category.

Win, Lose, or Adapt Game Resources

Win, Lose, or Adapt

Game Instructions

1) Play in groups of six to eight with two decks of playing cards randomly mixed and facedown in a central pile. These cards represent your food source. Each player has a Bird/Player identification card that specifies your beak type and particular food source (a combination of playing cards).

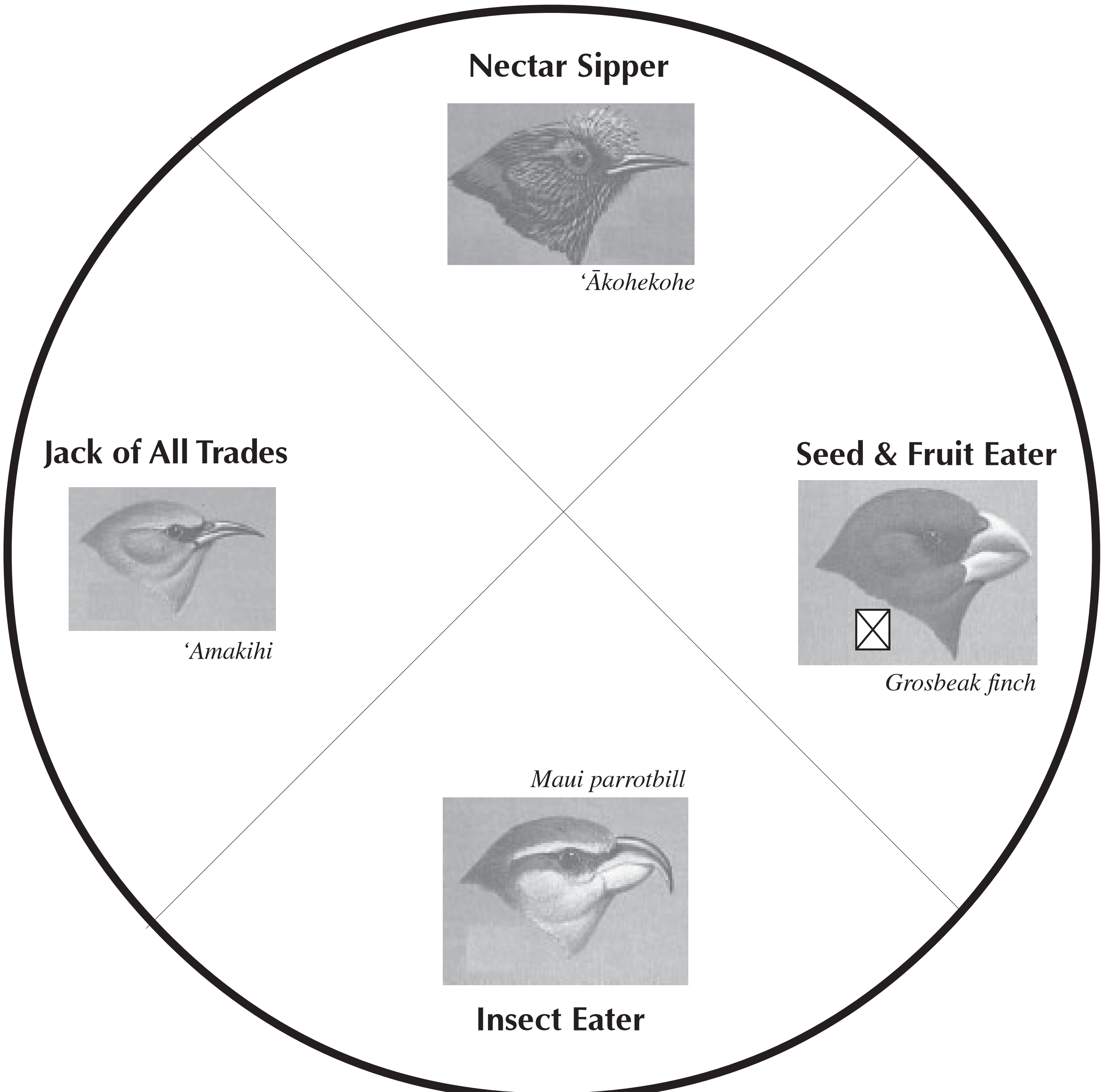
2) Your instructor will begin each of the five rounds of this game by reading a "Scenario Card" with instructions about how many cards each player is to draw and information concerning the beginning of the round.

3) In each two-minute round, you must try to collect as much of your food source as possible.
   - Draw the specified number of playing cards from the central pile. When the two-minute round begins—
   - Draw one playing card at a time, and decide whether to keep it. (Do not take turns drawing playing cards. All players will draw and return playing cards simultaneously, racing each other to collect your food source.)
     If you keep the card, discard one playing card from your hand facedown on the pile.
     If you do not keep the card, return it facedown on the pile.
   - Draw another playing card and continue.
   - Place the food source you collect faceup on the table in front of you, and draw enough playing cards from the central pile to replace the playing cards you put down.
   - Always maintain the original number of playing cards in your hand.
   - Continue playing in this fashion until the two-minute round is up.

4) At the end of each round, tally up the number of food sources each player collected, and follow the instructions on the "Food Competition Action Chart" to determine the winners of the round and the appropriate actions for each player. Ties are resolved by drawing a playing card from the central pile. The high playing card wins the tie. Aces are low.

5) In preparation for the next round, return your playing cards to the central pile and mix them up.

Beak-Type Wheel



Illustrations: H. Douglas Pratt, Jr.

Bird/Player Identification Cards

For each group of eight students, make eight copies of this sheet, for a total of eight cards that represent each beak type. Use card stock or another heavy paper. Cut apart on the dotted lines.

Jack of All Trades

Your beak shape allows you to prod, nip, and probe, taking advantage of all food sources. But since your beak is not specifically adapted to any one source of food, you're at a bit of a disadvantage when specialized birds are around.

Your food source
Three-of-a-kind of any cards, Ace through King, any suit

Collect as many as you can in each round!

Seed & Fruit Eater

Your beak crushes, slices, and pries to get through the husks, pods, and fleshy fruits surrounding the seeds you eat.

Your food source
Pair of cards, 6 through 9, any suit

Collect as many as you can in each round!

Nectar Sipper

Your tubular tongue and petal-probing beak is well-suited to sipping nectar from flowers. Your probing beak and feathers also transfer pollen from one flower to another, providing a function important to plant reproduction.

Your food source
Pair of cards, Ace through 5, any suit

Collect as many as you can in each round!

Insect Eater

Your beak probes the nooks and crannies of shrubs and trees, sometimes probing beneath the bark, to search out insects that hide there.

Your food source
Pair of cards, 10 through King, any suit

Collect as many as you can in each round!

Food Competition Action Chart

Ties are resolved by drawing a card. The player with the higher card wins. Aces are low.

Winner or Loser	Players	Action
The Winners These birds were the most successful at feeding and successfully reproduced, multiplying their numbers significantly.	The two birds that collected the MOST food	These birds thrived and so did their young, so each of these players "recruits" one of the players that died. The recruited player takes a matching bird identification card, representing the new generation.
The Unsuccessful These birds were not successful at feeding, and they died.	The two birds that collected the LEAST food	These birds "die" by turning in their identification cards. They then join the population of one of the birds that successfully reproduced by taking a bird identification card that matches one of the successful players.
The Survivors These birds were successful at feeding to keep themselves and some of their young alive, but they were at a definite disadvantage in the competition for food.	All other birds	These birds survived, but did not thrive. Each of these players draws a card to evolve to a new beak type, enabling them to exploit a different food source. • **Red suit** = Trade in your I.D. card for the next bird type in a CLOCKWISE direction on the beak-type wheel. • **Black suit** = Trade in your card for the next bird type COUNTER-CLOCKWISE.

Scenario Cards

Round 1 Scenario and Instructions

1) Each player takes one "jack of all trades" player identification card.

2) Each player draws **five** playing cards from the central pile.

3) Read Scenario #1:

This game loosely follows what scientists believe to be the story of a small flock of finches and their descendants, which eventually evolved into at least 52 species of endemic birds collectively known as the Hawaiian honeycreepers.

The scene: The island of Kaua'i, three to four million years ago—or so. You are part of a small flock of finch-like birds that are blown by a great hurricane to this island, more than 2,500 miles from your North American or Asian continental homeland. On Kaua'i, you and the other members of your flock find a variety of food sources: nectar from flowering plants, seeds, fruit, and insects. Your beak shape allows you to take advantage of all of these food sources—you are a "jack of all trades" or a "generalist," probably similar to today's *'amakihi*.

Important to the survival of any individual within a species—and, more broadly, any species—is its ability to acquire enough food to live, reproduce, and feed its young. Your ability to compete for food will determine whether you survive and reproduce.

In each round of this game, the playing cards represent your food source. Look on your bird identification card to see what you are trying to collect.

You'll try to collect as many of the food items listed on your identification card as you can during each round. Each round lasts two minutes—Wait until I say "begin" before you start collecting your food, and stop collecting as soon as I say "stop."

Round 2 Scenario and Instructions

1) Each player draws **five** playing cards from the central pile.

2) Read Scenario #2:

An eon passes—maybe a million or two million years—and the original flock of birds produces generation after generation. Some birds survive and reproduce, passing along their genetic information and characteristics to their young. Over time, birds with certain characteristics, such as slightly different beak shapes, were able to successfully exploit certain food types, and the birds with those characteristics thrived and reproduced, passing these characteristics along to future generations. Today, we know this process as "natural selection."

As time went on, these characteristics became so pronounced that different species emerged from the original flock of birds, which were all basically the same. These species are represented on your "Beak-Type Wheel."

So we come to this point, where we have species of birds with different beak shapes exploiting different types of foods. The birds and species that are generalist feeders, like the original "founder flock," compete with other birds and species that are adapted to specialized food sources.

Begin Round 2.

Round 3 Scenario and Instructions

1) Each player draws **five** playing cards from the central pile.

2) Read Scenario #3:

Another eon passes—another couple million years—and evolution continues. During this time, descendant species of the original founder flock find their way to the newly emerging island that we call Maui, flying from island to island in search of food.

On Maui, about a million years ago today, the competition for food continues . . .

Begin Round 3.

Round 4 Scenario and Instructions

1) Each group removes approximately one-third of the playing cards remaining in their central food pile before beginning this round, and sets them aside for the remainder of the game.

2) Each player draws **four** playing cards from the central pile.

3) Read Scenario #4:

   Another eon passes—a shorter one this time—and evolution continues. Late in this time frame, Polynesian settlers arrive on Maui. Over time, these original Hawaiians cleared land for their farms and villages and took trees from the forest for building. As their numbers multiplied, their impact on the land increased, and many of the food sources for the species that descended from the original Hawaiian finches were in shorter and shorter supply.

   Begin Round 4.

Round 5 Scenario and Instructions

1) Each group again removes approximately one-third of the playing cards remaining in their central food pile before beginning this round, and sets them aside for the remainder of the game.

2) Each player draws **three** playing cards from the central pile.

3) Read Scenario #5:

   A few hundred years pass, and Europeans “discover” Hawai‘i. Over time, forests are cut down for sale overseas, cattle and other domestic livestock graze forests and shrublands, destroying even more habitat for native Hawaiian birds. Feral pigs and goats damage the native forests, and introduced species compete with native birds for food. Rats and mongoose prey on native bird eggs and chicks. Many native birds are forced to live exclusively at upper elevations because mosquitoes carrying bird diseases inhabit lower elevations.

   Begin Round 5.

Final Scenario

1) At the end of Round 5, read the following passage:

   That brings us to today. Out of the 52 species of Hawaiian honeycreepers, the descendants of finch-like ancestors that arrived on the Hawaiian Islands before Maui even existed, only 22 survive today. Of these, 14 are classified as endangered or may already be extinct. Only eight surviving species are not classified as endangered. What do you think could be happening to these native species?

Win, Lose, or Adapt: Questions About the Game

1) In the game, the “jacks” had to get three of a kind of any card, while the specialized birds only had to get a pair but in a certain numeric range. How do you think this division of food items parallels what happens in nature?

2) What effect do you think declining food sources would have on overall population size of native birds? Why? What would you need to know in order to predict the effects on different types of birds (i.e., nectar sippers, etc.)?

3) If all food sources are declining equally rapidly, which of the four types of birds do you think would have the advantage? Why?

4) List and explain at least two ways in which you think this game is similar to/different from the actual process of evolution and adaptation.

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Activity #2

Adaptive Radiation in Rain Forest Birds

● ● ● **In Advance** *Student Reading*

- Assign the Student Page "Adaptive Radiation in Hawaiian Honeycreepers" (pp. 22-26) as homework.

● ● ● **Class Period One** *Adaptive Radiation Discussion*

Materials & Setup

For each student

- Student Page "Adaptive Radiation in Hawaiian Honeycreepers" (pp. 22-26)
- Student Page "Adaptive Radiation in Hawaiian Honeycreepers: Questions on the Reading" (pp. 27-28)

Instructions

1) Have students complete the Student Page "Adaptive Radiation in Hawaiian Honeycreepers: Questions on the Reading" in class.

2) Spend the remainder of the class discussing adaptive radiation and the homework reading, beginning with student responses to the questions.

Journal Ideas

- Many native birds are not found in low-elevation areas on Maui. Do you think that native birds once occupied these lowland areas? How would you go about finding out?
- Do you think anything should be done to protect the remaining Hawaiian honeycreepers? Why or why not?
- Keeping in mind the different human-caused pressures that have led to declines and extinctions among Hawaiian honeycreepers, what do you think can be done to protect the species that remain?
- Imagine being a traditional Hawaiian bird catcher, collecting thousands of feathers over your lifetime. What do you think it would have been like to work mostly alone in the forests of the gods?

Assessment Tools

- Student Page "Adaptive Radiation in Hawaiian Honeycreepers: Questions on the Reading" (teacher version, pp. 20-21)
- Participation in class discussion
- Journal entries

Teacher Version

Adaptive Radiation in Hawaiian Honeycreepers: Questions on the Reading

1) Define adaptive radiation, and explain its relationship to endemic species. Give one example of adaptive radiation in Hawaiian species other than honeycreepers.

Adaptive radiation is the evolution of many species from a single ancestor.

Well-reasoned responses about the relationship between adaptive radiation and endemism are acceptable. Possible relationships include:

- Adaptive radiation results in many endemic species (species that evolved here and are found nowhere else in the world) that are closely related to each other because of their common ancestor, and
- Because species are evolving in response to local conditions, adaptive radiation may result in species that are "narrowly endemic," or restricted to a small range or a single island.

Examples include Hawaiian *Drosophila* flies and Hawaiian lobeliads. There are many others that students may have learned about outside this unit, including the silversword alliance which includes the *ʻāhinahina* or Haleakalā silversword.

2) Why are fossil records valuable sources of information to scientists studying the evolution of native bird species?

Well-reasoned responses are acceptable. Fossil records enable scientists to identify previously unknown species and establish their relationships with existing species. Among Hawaiian honeycreepers, for example, 18 species are known only from fossil records. That's 35 percent of all known honeycreeper species. Our understanding of the scope of adaptive radiation among honeycreepers would be much narrower if not for the fossil record.

3) Is the shift in the size of *ʻiʻiwi* bills over the last 100 years an example of adaptive radiation in action? Explain your answer.

Well-reasoned responses are acceptable. Two possibilities:

- The shift in *ʻiʻiwi* bill size is probably not adaptive radiation in action because it is likely to be taking place across the entire species, so the changes that are taking place are probably not going to result in the creation of a new species. The extinction of the *ʻōʻō* probably affected the *ʻiʻiwi* across much of its range, as did the decline of the preferred food source, Hawaiian lobeliads.
- If there are islands or large stretches of habitat in which Hawaiian lobeliad populations are protected or restored and other places where they are not, then we may be seeing adaptive radiation in action, as the habitat for some populations of *ʻiʻiwi* would favor their existing bill size, and the habitat for others would favor a shorter bill, possibly leading to species differentiation over a long period of time.

4) Using what you have learned about evolution and adaptation, explain why extinctions of rain forest bird species have happened—and continue to occur—so rapidly in the face of human-caused changes to native Hawaiian rain forests.

Well-reasoned responses are acceptable. Two possibilities:

- Human-caused changes such as habitat destruction, pressures by introduced species, and introduced diseases are altering conditions for native birds so quickly that evolution cannot keep up. The honeycreepers took millions of years to evolve, but humans have caused dramatic changes in their environment within hundreds of years.
- Human activity has contributed to many different pressures on native birds including habitat destruction, predation and competition by introduced species, and disease. A species that might be able to adapt and survive in the face of a single human-caused pressure may not fare so well when there are multiple pressures working against its survival.

Adaptive Radiation in Hawaiian Honeycreepers

The Hawaiian Islands are the most isolated archipelago on the planet. Here, we are more than 2,000 miles away from the nearest continent and some 1,000 miles away from the closest Pacific atolls. Because of this isolation, over millions of years, relatively few plant and animal species arrived on the islands. The “three Ws” (wind, waves, and wings) are used to describe the means by which species arrived here. From a small collection of “founding species” descended all of the animals and plants that are native to Hawai‘i. The Hawaiian rain forest is a hotbed of “endemism.” Of its native inhabitants, a large proportion are unique to these islands.

In contrast to “indigenous” species, Hawaiian endemic species evolved into a new species after arriving here from somewhere else. Indigenous species have remained relatively unchanged since their arrival and are not unique to Hawai‘i. Among the endemic forest birds, most species belong to a group known as the Hawaiian honeycreepers. All of the honeycreeper species are thought to have evolved from a single finch species that arrived on the islands more than 15 million years ago. This process of “adaptive radiation” has, over time, resulted in honeycreepers that are very different from each other and adapted to many different environments.

The oldest of today’s main islands, Kaua‘i, is only about five million years old. So much of the early evolution of the honeycreepers probably happened on other, older islands in the chain. Through a process called “interisland dispersal,” the ancestors of the honeycreeper species we know today colonized the new islands, even as their old homelands were being slowly eroded away. These new islands may have offered different habitat for the birds, which over time could have further radiated into new species.

In the 1970s, paleontologists began in earnest to collect partially fossilized bird remains from sand dunes, lava tubes, caves, and sinkholes in the Hawaiian Islands. This fossil record revealed many species of honeycreepers that were already extinct by the time Western scientists had started identifying and describing Hawaiian birds. Most of these extinctions were most likely a result of the impacts of the Hawaiian people: competition or predation by Polynesian introductions, conversion of lowland habitats into agricultural areas, and killing of birds for food and other human uses.

Hawaiian Honeycreepers at a Glance

- Thought to have evolved from a single species of finch.

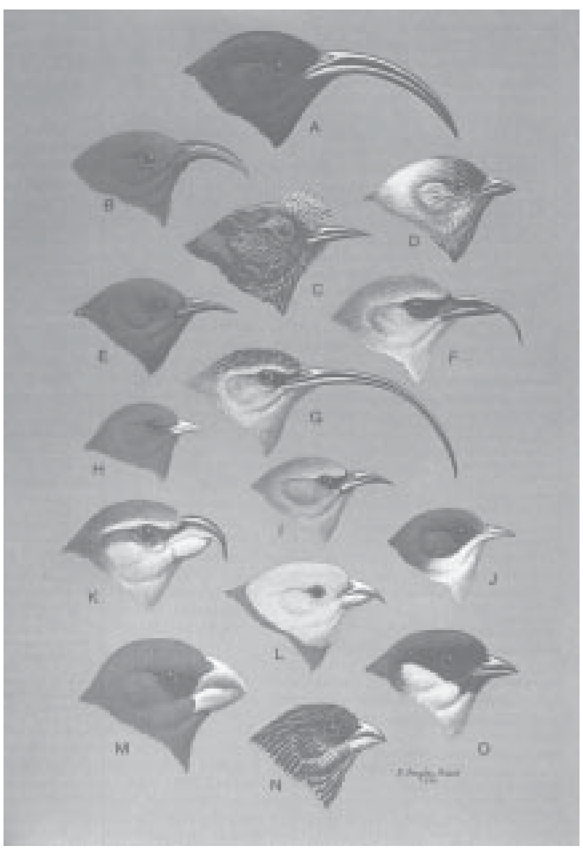
- Fifty-two species are thought to be part of the Hawaiian honeycreeper subfamily.

Eighteen species, known only from fossil record, were probably extinct by 1778.	35 percent
Twelve species have gone extinct since 1778.	23 percent
Fourteen surviving species are classified as endangered, some may already be extinct.	27 percent
Eight surviving species are not classified as endangered.	15 percent

In addition to uncovering evidence of bird extinctions, fossil research has helped to shed new light on the true extent of adaptive radiation in Hawaiian honeycreepers. From the single ancestral finch species, at least 52 honeycreeper species are known to have evolved. What caused this remarkable formation of new species?

Adaptive Radiation

Adaptive radiation is often thought of as being driven by the need or opportunity for plants or animals to live in habitats other than the ones to which they are best adapted. It is easy to see how such needs and opportunities could arise for birds arriving on the Hawaiian Islands from other parts of the world. The Hawaiian honeycreepers evolved into species with different primary food sources: nectar, hard seeds, soft fruit, and insects and larvae. Some honeycreeper species have diets made up of combinations of these food sources.



Variations in bill morphology of selected Hawaiian honeycreepers
(Illustration: H. Douglas Pratt, Jr.)

Their beak structure and even their leg and facial muscles reflect their diet and how they forage for food.

Some nectar-eating honeycreepers have beaks that are shaped to fit specific flowers. This is evidence of coevolution, in which honeycreepers and flowering plants evolved together, the birds feeding on the nectar and in turn spreading pollen from flower to flower. Birds and flowers evolved specialized relationships, of which the *ʻiʻiwi* and Hawaiian lobeliad plants are an excellent example. The long, curved bill of the *ʻiʻiwi* is perfectly suited to gathering nectar from the long, tubular, curved flowers of many lobeliad species.

Many factors are thought to have influenced adaptive radiation in Hawaiian honeycreepers, including the following:

Isolation and Dispersability

Populations of a bird species that remain isolated from each other can, over time, evolve into separate species. In general, birds can easily disperse from one place—or island— to another by flying. But the pattern of species and island-specific subspecies of honeycreepers suggests that some species were more likely to do so than were others.

Some scientists believe that insect-eating honeycreepers have a more reliable source of food than do species that feed on fruit or nectar. They hypothesize that "frugivorous" (fruit-eating) and "nectivorous" (nectar-feeding) birds are more likely to fly between islands looking for food in lean years. Because the "insectivores" (insect-feeders) had less reason to move around, they remained more isolated and developed into more species and subspecies.

Other scientists believe that there is not such a clear link between eating habits and interisland dispersal. Instead, they distinguish between common "generalists" such as the *ʻapapane* and *ʻamakihi* that are widespread across the islands on the one hand, and specialized seed eaters and nectivores on the other hand. Generalists are able to feed on a variety of food types. The more specialized eaters, some scientists maintain, would have been more likely to stay where their food source was and further evolve in that place. The generalists would have been more likely to fly from island to island.

Adaptation to Food Resources

Birds can rapidly adapt to new types of food or changes in the abundance of food sources. Over time, these adaptations (physical or behavioral changes) can result in the emergence of new species. In 1984 and 1985, studies of endangered Laysan finches that had been introduced in 1967 to Pearl and Hermes Reef, showed significant differences had already developed between the Pearl and Hermes finches and their ancestors on Laysan. The differences appeared to be a response to differences in food availability. If those differences turn out to be genetically linked, then evolutionary change had occurred among these birds in fewer than 20 generations.

Intraspecies Food Competition

Competition for food among members of the same species can lead to "adaptive shifts" or changes. Less competitive members of the species may shift to feeding on a different size or type of food, and over time this division of food can lead to bills that are specialized to this available food source.

'I'iwi (Photo: Eric Nishibayashi)

Other Rain Forest Examples of Adaptive Radiation

- The Hawaiian *Drosophila* flies: Over 500 species of flies in the Drosophilidae family have been identified in Hawai'i, all of which evolved from a single common ancestor species. Nearly one-quarter of the known species in this family are found in Hawai'i, including many that are "narrowly endemic." That means that they occur in only a very small area.
- Hawaiian lobeliads: Six of seven genera of this group of plants are endemic to Hawai'i. The 98 species in the genera *Cyanea, Clermontia, Delissea,* and *Rollandia* are considered by many scientists to be the largest group of Hawaiian plants to have evolved from a single immigrant species.

Evolution is Not Over

Evolutionary changes in Hawaiian honeycreepers did not end at some time in the past. In fact, there is evidence that rapid evolutionary changes have occurred within the past 100 years, in response to human-induced extinctions and habitat changes. Given the fact that the honeycreepers evolved over *millions* of years, to measure significant changes in *one hundred* years indicates rapid natural selection.

Here is an example of such a rapid shift:

In the early 1990s, a group of biologists compared body measurements of live *'i'iwi* with museum specimens collected prior to 1900 (Smith, et al., 1995). Early studies of the *'i'iwi*—prior to 1900—reported that the long, curved flowers of Hawaiian lobeliads were this bird's preferred food. Now, however, *'i'iwi* feed mainly on the open flowers of *'ōhi'a*, which do not have tubular, curved flowers.

What might have caused this change in diet? Researchers point to two factors. The first is that the lobeliads, once a prominent part of the understory of Hawaiian rain forests, are now rare. During the 20th century, habitat degradation and grazing by feral ungulates induced the extinction of 25 percent of Hawaiian lobeliad species. Most of the species that remain are rare or endangered. So the preferred food of the *ʻiʻiwi* is greatly reduced.

Researchers suggest the second factor influencing this dietary shift was the extinction of the *ʻōʻō*. The *ʻōʻō* was a Hawaiian honeyeater, another native Hawaiian bird not related to the honeycreepers. This bird was behaviorally dominant over the *ʻiʻiwi*, keeping the *ʻiʻiwi* from feeding heavily in the favored trees of the *ʻōʻō*: the *ʻōhiʻa*. By 1900, the *ʻōʻō* was extinct, and as the lobeliads declined over the course of the 1900s, the *ʻiʻiwi* shifted its foraging emphasis to *ʻōhiʻa* flowers.

Birds that feed most efficiently on *ʻōhiʻa* flowers, such as the *ʻapapane* and the *ʻākohekohe*, have short bills to exploit this food source. Researchers hypothesized that a shift in diet away from the long, tubular, curved lobeliad flowers to the open *ʻōhiʻa* flowers would have resulted in selective pressures which favored shorter bills over longer bills.

The biologists tested this hypothesis by comparing bill measurements and other body measurements of live *ʻiʻiwi* with museum specimens collected prior to the extinction of the *ʻōʻō*. Evaluating the data they collected, they found that the upper mandible (beak portion) became shorter, while overall body size stayed the same. The results of their analysis suggest "the longer billed birds, presumably due to lower feeding effiencies on *ʻōhiʻa,* were lost over time as selection favored shorter and possibly straighter bills."

As human-induced extinctions and declines of native species continue, the structure of Hawaiian natural communities is changing rapidly. These changes open the possibility for rapid evolutionary shifts, such as the one that appears to be happening with the *ʻiʻiwi*.

Ongoing Threats

Of the 22 known surviving species of Hawaiian honeycreepers, 14 are considered endangered, and some of these may already be extinct. What is contributing to this loss of species today?

- Habitat destruction: The Maui parrotbill is an illustrative example of the impact of habitat destruction. By the 1890s, it was already rare in the remaining *koa*-dominated rain forests. These *koa* forests were destroyed, largely by wildfires, browsing by introduced animals, and logging. Today, the parrotbill survives only in higher-elevation *ʻōhiʻa* forests, where it is an extremely rare bird.

- Avian malaria and other diseases: Like many Hawaiian honeycreepers, the rare *ʻākohekohe* is thought to be highly susceptible to avian malaria, a disease introduced early this century with nonnative birds. The disease is transmitted by a nonnative mosquito and is believed to prevent honeycreeper populations from surviving in lower-elevation forests. Mosquitos rarely occur above 1200 meters (3936 feet) elevation. Many native birds escape infection only while they remain in upper-elevation forests.

- Predation by cats, mongooses, and rats: These animals eat native bird eggs and chicks, and sometimes even adult birds, especially those tending their young.

These pressures are happening at a rapid rate, much more quickly than many bird species can adapt. The honeycreepers that are faring the best tend to be those that can adapt to a broad range of habitats. The most common honeycreepers on Maui and in Hawaiʻi are the *ʻapapane* and the *ʻamakihi*. Both of these birds range from the rain forests into upper-elevation shrublands and even into planted forests. As the *‘i‘iwi* shows, however, rapid evolutionary shifts are possible, and that possibility—along with efforts at habitat protection, feral animal control, and research into avian diseases—may spell survival for some of the remaining Hawaiian honeycreeper species.

Sources

Freed, L. A., “Extinction and Endangerment of Hawaiian Honeycreepers: A Comparative Approach,” in Landweber, L. F., and A. P. Dobson (eds.), *Genetics and the Extinction of Species*, Princeton University Press, Princeton, New Jersey, 1999, pp. 137-162.

Freed, L. A., S. Conant, and R. C. Fleisher, “Evolutionary Ecology and Radiation of Hawaiian Passerine Birds,” in Kay, E. A. (ed.), *A Natural History of the Hawaiian Islands, Selected Readings II*, University of Hawai‘i Press. Honolulu, 1994, pp. 335-345.

Givnish, T. J., K. J. Sytsma, J. F. Smith, and W. J. Hahn, “Molecular Evolution, Adaptive Radiation, and Geographic Speciation in *Cyanea (Campanulaceae, Lobelioideae)*,” in Wagner, W. L., and V. A. Funk (eds.), *Hawaiian Biogeography: Evolution on a Hot Spot Archipelago*, Smithsonian Institution, Washington, DC, 1995, pp. 288-337.

Juvik, James O., “Biogeography,” in Juvik, Sonia P., and James O. Juvik (eds), *The Atlas of Hawai‘i*, 3rd ed., University of Hawai‘i Press, Honolulu, 1998, pp. 103-106.

Medeiros, Arthur C., and Lloyd L. Loope, *Rare Animals and Plants of Haleakala National Park*, Hawai‘i Natural History Association, Hawai‘i National Park, Hawai‘i, 1994.

Smith, T. B., L. A. Freed, J. K. Lepson, and J. H. Carothers, “Evolutionary Consequences of Extinctions in Populations of a Hawaiian Honeycreeper,” *Conservation Biology*, Vol. 9, No. 1, 1995, pp. 107-113.

Adaptive Radiation in Hawaiian Honeycreepers: Questions on the Reading

1) Define adaptive radiation, and explain its relationship to endemic species. Give one example of adaptive radiation in Hawaiian species other than honeycreepers.

2) Why are fossil records valuable sources of information to scientists studying the evolution of native bird species?

3) Is the shift in the size of *ʻiʻiwi* bills over the last 100 years an example of adaptive radiation in action? Explain your answer.

4) Using what you have learned about evolution and adaptation, explain why extinctions of rain forest bird species have happened—and continue to occur—so rapidly in the face of human-caused changes to native Hawaiian rain forests.

Activity #3

Rain Forest Birds Research Projects

● ● ● Class Period One *Discussion and Research Topics*

Materials & Setup

For each student

- Student Page "Rain Forest Birds Research Projects: Topics and Resource List" (pp. 30-35)

Instructions

1) Students will be doing independent research projects on topics related to birds in Hawaiian rain forests, including the rain forest on Haleakalā. Brainstorm a list of topics or questions students find interesting. Students may select topics from that list or come up with another of their own choosing. Use the Student Page "Rain Forest Birds Research Projects: Topics and Resource List" in class to help spark students' thinking, or hand it out to students at the end of class.

2) You will need to set the parameters for these research projects, such as:
   - How long students will have to do their research;
   - When they will need to hand in a research plan, including the question they are researching and sources of information (this research plan will help keep their projects on track and enable you to help students target their efforts);
   - How students will present their findings (options include a research paper, class presentation, poster display, or multimedia presentation); and
   - How research and presentations will be evaluated.

Note

- Depending upon the needs of your students, you may need to schedule some class time to help students refine their research questions, identify more sources of information, or develop reports.

Assessment Tools

- Research plans
- Research reports or presentations

Rain Forest Birds Research Projects: Possible Topics and Resource List

There are many interesting research topics having to do with native birds in Hawaiian rain forests. This background sheet suggests a handful of topics for which information is readily available. Then it lists many written and internet resources for research, linking them with these topics. It also lists useful sources of general background information.

Possible Research Topics

1) **Basic biology and natural history of a particular family, genus, or species of birds**
Several species and families of native Hawaiian birds have been thoroughly studied. You could select one or more species, a genus, or even the whole family of honeycreepers, and learn about them in depth. You may also learn about topics such as co-evolution, in which native plant and bird species evolved together with special adaptations that are beneficial to both.

2) **Human-caused changes: Habitat alteration and introduced species**
From the time that Polynesians first settled on the Hawaiian Islands, people have been changing the environment in which native Hawaiian birds live. You could study how humans have changed bird habitat—or specific habitats such as the *koa* forest—and what has happened to native bird species as a result. Or you could study the threats that introduced species pose to native birds.

3) **Avian (bird) malaria as a threat to native bird species**
Early in the 1900s, nonnative birds that carried a disease called avian malaria were brought to the Hawaiian Islands by people. Avian malaria is transmitted to native birds by a nonnative mosquito. You could learn more about this disease, how and why it threatens native birds, how it is spread, and the possible relationship between pig rooting, mosquito reproduction, and the spread of avian malaria. You could also explore why native birds seem to escape infection at elevations above 1200 meters (3936 feet), and how this might change because of global warming.

4) **Bird catching and hunting and the cultural significance of birds in traditional Hawaiian society**
In Hawaiian society, birds were hunted and captured for a variety of reasons, including as a source of food and feathers. Bird catchers played an important role in this culture. You could learn more about how and why Hawaiians caught birds, which species were prized, and what is known about the effects of bird hunting and catching on populations of native birds. You could also learn about the cultural significance of different bird species to native Hawaiians.

5) Extinction of Hawaiian bird species

Throughout the Pacific Islands, it is estimated that more than 2000 species of land birds became extinct after human settlement. You could learn more about what scientists know about extinct native birds based on historical records and the recovery of partially fossilized bird remains from sand dunes, lava tubes, caves, and sinkholes. You could also explore causes of extinction and why native Hawaiian birds were so susceptible to the pressures that came along with human settlement of the islands.

6) Efforts to protect or revive threatened and endangered native bird species

Today, there are many efforts to protect native bird species that are in danger of extinction. You could learn about how species are classified as threatened or endangered, which Hawaiian species are so classified, and what is being done to protect one or more of these species.

Resources for Research: A Beginning List

Sources of Information (Print)	General Information	Bird Biology and Natural History	Human-cause changes	Avian malaria	Bird catching & cultural significance	Extinction	Protecting bird species
Berger, A. J. , *Hawaiian Birdlife*, 2nd ed., University of Hawai'i Press, Honolulu, 1981. This is an extensive resource; common Maui birds are covered on pp. 127-170.	•	•	•	•	•	•	•
Berger, A. J. , *Bird Life in Hawai'i*, Island Heritage Publishing. Aiea, Hawai'i, 1996. This book gives a one- to two-page description and color drawing for each bird and discusses habitat alteration and non-native birds on pp. 7-8, 42-70.		•	•		•	•	
Carlquist, Sherwin, *Hawai'i, A Natural History*, Pacific Tropical Botanical Garden, Kaua'i, Hawai'i, 1980. In chapter 11 (p. 190-212) a section on the honeycreepers and other birds covers life history, diet, nest descriptions, threats such as avian malaria, and sketches.		•					
Hawai'i Audubon Society, *Hawai'i's Birds*, Hawai'i Audubon Society, Honolulu, 1997. For each bird species there is a one- to two-page description about the bird's distribution, description, voice, and habits. The introduction talks about dispersal to the Hawaiian Islands, evolution, extinction, and other notes.	•	•			•		
Juvik, S. P., and J. O. Juvik (eds.), *Atlas of Hawai'i*. 3 rd ed., University of Hawai'i Press, Honolulu, 1998. "Birds" section by Sheila Conant (pp. 130-134) includes basic background, an insert on extinction, a discussion of honeycreepers and adaptation to food sources, and an overview of human impacts (avian malaria, non-native organisms). "Alien Species and Threats to Native Ecology" section by F. R. Warshauer (pp. 146-149) provides an overview of species introductions, including a look at the rate of introduction, types of organisms, and impact. "Biogeography" section by J. O. Juvik (pp. 103-106) provides an overview of means of dispersal of land plants and animals to Hawai'i.	•		•	•		•	
Medeiros, A. C., and L. L. Loope, *Rare Animals and Plants of Haleakala National Park*, Hawai'i Natural History Association, Hawai'i National Park, Hawai'i, 1994. Overview about birds in Hawai'i includes rare birds found in Haleakalā National Park, extinctions, and adaptive radiation. Provides specific information on three birds in the rain forest: the crested honeycreeper, parrotbill, and *nukupu'u*.	•	•				•	

Sources of Information (Print)	General Information	Bird Biology and Natural History	Human-cause changes	Avian malaria	Bird catching & cultural significance	Extinction	Protecting bird species
Stone, C. P., and L. W. Pratt, *Hawai'i's Plants and Animals: Biological Sketches of Hawai'i Volcanoes National Park*, University of Hawai'i Press, Honolulu, 1994. For the common forest birds, this book gives one to two pages of information including life history, description, distribution, value to Hawaiians, current threats, and drawings. Addresses avian malaria on pp. 214-215, 271.		•		•	•	•	•
Kepler, A. K. , *Hawaiian Heritage Plants*, Oriental Publishing Co., Honolulu, 1984. Discusses lobelias and bird catching, pp. 80-83; bird catching, chants, feather capes, pp. 107-111; *'elepaio* pp. 69-73; and *palila* pp. 86-88					•		
Pukui, M. K., and S. H. Elbert, *Hawaiian Dictionary*, University of Hawai'i Press, Honolulu, 1986. Definitions of different types of bird catchers and methods used: *kau manu, kia manu, kapili manu, kono manu, la au kia*					•		
Kamehameha Schools Bernice Pauahi Bishop Estate, *Life in Early Hawai'i: The Ahupua'a*, 3rd ed., Kamehameha Schools Press, Honolulu, 1994. Bird catching is addressed on pp. 16, 28, 43.					•		
Kepler, C. B., and A. K. Kepler, *Haleakala: A Guide to the Mountain*, Mutual Publishing, Honolulu, 1988. Common birds seen at Hosmer Grove, pictures & brief descriptions, pp. 33-34		•					
Freed, L. A., S. Conant and R. C. Fleisher, "Evolutionary Ecology and Radiation of Hawaiian Passerine Birds," in Kay, E. A. (ed.), *A Natural History of the Hawaiian Islands, Selected Readings II*, University of Hawai'i Press. Honolulu, 1994, pp. 335-345. This is a summary of research and findings on adaptive radiation in Hawaiian passerine birds, focusing on Hawaiian honeycreepers.	•	•					
Attenborough, D., *The Life of Birds*, BBC Books, London, England, 1998. This is a general reference book on bird behaviors and biology, including flightlessness, feeding, mating and rearing young. Although not specific to Hawaiian species, this book provides background, context and examples from all over the world.	•						

Sources of Information (Internet)	General Information	Bird Biology and Natural History	Human-cause changes	Avian malaria	Bird catching & cultural significance	Extinction	Protecting bird species
U.S. Geological Survey, "Status and Trends of the Nation's Biological Resources: Hawai'i and the Pacific Islands" at <biology.usgs.gov/s+t/SNT/noframe/pi179.htm>.	•	•	•	•		•	
U.S. Geological Survey, "Hawaii's Environment Benefits from Geographic Isolation" at <hvo.wr.usgs.gov/volcanowatch/1999/99_03_18.html>.				•			
"Hawaii's Endangered Species" at <naalehuel.k12.hi.us > Student pages include a site about endangered species created by students.		•		•		•	•
U.S. Fish and Wildlife Service, "Threatened and Endangered Species" at <pacificislands.fws.gov/wesa/endspindex.html>. Site about threatened and endangered species in the Pacific, including Hawaiian plants and animals	•	•				•	•
"Researchers at Zoo Work to Save Hawaiian Birds from Extinction," (*Molecular Genetics: Research Reports* No. 93, Summer 1998) at <www.si.edu/researchreports/9893/birds.htm>.	•		•	•			
"Searching for Hope in the Family Tree," (*National Wildlife*, April/May 1998) at <www.nwf.org/natlwild/1998/honey.html>.				•			
Hawai'i Biological Survey at <hbs.bishopmuseum.org/hbsl-navbar-0.html>. Includes information about endangered and threatened species						•	
Bryant, Peter J., "Islands, Chapter 12 in Biodiversity and Conservation, A Hypertext Book" at <darwin.bio.uci.edu/~sustain/bio65/lec12/b65lec12.htm# Diseases>.	•		•			•	
"Extinction and Biodiversity" at <www.teaching-biomed.man.ac.uk/bs1999/bs146/biodiversity/Extinction.html>. Not Hawai'i or bird-specific	•					•	
Hawai'i Natural Heritage Program at <www.abi.org/nhpl/us/hi/iiwi.htm> (*'i'iwi* life history) < www.abi.org/nhpl/us/hi/pbill.htm> (Maui parrotbill life history)		•					

Sources of Information (Internet)	General Information	Bird Biology and Natural History	Human-cause changes	Avian malaria	Bird catching & cultural significance	Extinction	Protecting bird species
Smithsonian Institution, "*'I'iwi* Life History" at <www.si.edu/organiza/museums/zoo/zooview/exhibits/birdhs/iiwi.htm>.		•					
"Hawaii's Endemic Birds" at <biology.usgs.gov/s+t/noframe/t018.htm>.	•	•	•	•		•	•
"National Geographic On-Line Index" at <www.nationalgeographic.com/publications/explore.html>.	•						