

Investigating the Ecology of Invasive Mosquitoes on Native Birds in Hawai`i

Essential Question:

- How do biotic and abiotic environmental factors explain the historic, present, and future prevalence and distribution of avian malaria and native (indigenous) forest birds in Hawai`i?

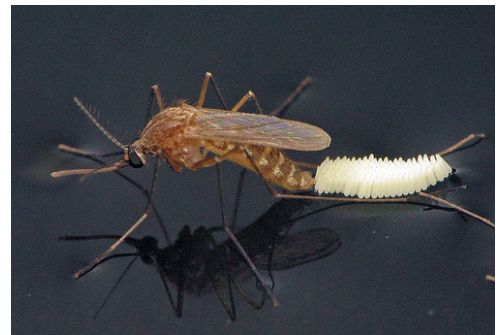
Learning objectives: Students will be able to:

- Define the terms: biotic, abiotic, endemic, indigenous, introduced, and invasive.
- Describe the history of the introduction of invasive mosquitoes in Hawai`i.
- Interpret and analyze real data to explain the effects of biotic and abiotic factors on ecosystems, and relate this to understanding how invasive species affect Hawaiian ecosystems.

Background:

Mosquitoes were introduced to Hawai`i in the early 1800's. Eight non-native mosquito species have become established since then, including two serious vectors (a vector is an organism that can carry and transmit diseases) that threaten human health, as well as one vector of avian diseases that has contributed to the decline and extinction of many of Hawai`i's iconic native forest birds. Because they damage the ecosystem here,

The presence of mosquitoes in Hawai`i represents a persistent and serious threat to public health, as well as to the economy and our ecosystems. Diseases such as chikungunya, dengue, and yellow fever affect hundreds of millions of people worldwide, causing debilitating symptoms and sometimes death. More recently, the Zika virus has spread through the Americas, causing birth defects and neurological disorders. These human diseases are transmitted by two mosquitoes, the yellow fever mosquito (*Aedes aegypti*) and the Asian tiger mosquito (*Aedes albopictus*), natives of Africa and Asia respectively. Both of these species have invaded Hawai`i and are responsible for outbreaks of dengue fever, such as during the outbreak in Hawai`i from 2015-2016. Similarly, either of these two species could sustain a Zika virus outbreak sparked by the arrival of an infected traveler. Additionally, the Southern house mosquito (*Culex quinquefasciatus*; shown above) transmits the avian malaria parasite, a protist called *Plasmodium relictum*, and avian pox virus, both major factors in the extinction of more than half of Hawai`i's honeycreepers. The Southern house mosquito can also transmit West Nile virus. This mosquito and the pathogens it carries threaten extinction of most of the remaining 17 species of the endemic birds of Hawai`i that are found nowhere else on Earth.



The Southern house mosquito, *Culex quinquefasciatus*, lays "rafts" of over 100 eggs, that will hatch 24-30 hours later. A female will lay up to 5 egg rafts in her lifetime. Both the number of eggs and number of egg rafts are dependent on temperature and rainfall.



i'iwi were once described as "ubiquitous" on all of the major Hawaiian islands. Today, with their range severely retracted, more than 90 percent of the remaining i'iwi population is clustered in mountain forests on the big island of Hawaii.

A single mosquito bite can transfer malaria parasites to a susceptible bird, where the death rate may exceed 90 percent for some species. One of those species is the i'iwi, *Drepanis coccinea*, a Hawaiian honeycreeper, shown in the picture to the left. As a result, many already threatened or endangered native birds now only survive in disease-free refuges found in high-elevation forests where mosquito populations and malaria development are limited by colder temperatures. Unlike continental bird species, island birds cannot move northward in response to climate change or increased disease stressors and must adapt or move to less hospitable habitats to survive.

The endemic birds of Hawai'i also have high cultural value. Native Hawaiians named most of the native bird species, and some birds were considered 'aumākua (personal guardians) in Hawaiian culture. Traditionally, Hawaiians resourced different birds for a variety of uses. The 'elepaio, for example, assisted canoe builders by revealing a rotten tree that would not be good for a canoe hull, and the feathers of the i'iwi and other birds were highly-prized as a form of payment for taxes. Their feathers would be used to make kähili (royal standards), 'ahu 'ula (cloaks), mahiole (helmets), and other royal objects that served as symbols of mana (power) belonging to the Ali'i (royalty). If and/or when we lose these birds, we also lose these important cultural resources.



This Hawaiian feather cloak, called a 'ahu 'ula, belonged to Princess Kekāuluohi Ka'ahumanu III. It is made of feathers from the Hawaiian O'o and the i'iwi.

Scientists know that historically, malaria has caused bird extinctions but changing climates could affect the bird-mosquito-disease system in unknown ways. As more mosquitoes move up the mountainside, disease-free refuges will no longer provide a safe haven for the most vulnerable species.

Let's explore what has happened historically, and think critically about what may happen in the future...

Background Questions:

1. Which mosquito species is responsible for the spread of avian malaria and avian pox in Hawai'i? Give the common and scientific name.

2. This same mosquito is responsible for the spread of West Nile Virus (WNV) across the United States. Examine the State of Hawai'i Department of Health Disease Outbreak Control Division's website (<http://health.hawaii.gov/docd/>). Click on "Diseases" and then "Diseases A-Z" and look for West Nile Virus. Have there been cases of WNV in Hawai'i? Why or why not?

3. Why do you think Hawai'i's indigenous birds are so susceptible to avian malaria? Explain using information about the natural history of the Hawaiian islands, as well as information you have learned in class about evolution, in your answer.

Part I: Prevalence and Distribution of I`iwi from 1977 to 2015 on the Big Island

The United States Geological Survey has been collecting data on Hawai'i's birds since the 1970s. Let's examine the difference in the number of i`iwi on the Big Island of Hawai'i over a 40 year span using a data set that was recently published where researchers counted the number of different Hawaiian bird species using transects (data observation plots) at several wildlife stations throughout Hawai'i island. To do so, you'll need to examine some data in the form of graphs and excel sheets and do your own analysis.

First, let's have a look at the diversity of birds (native and non-native). Recall that diversity includes both **species abundance** and **species richness**.

Define species abundance:

Define species richness:

Examine Figure 1 of the data set at the end of the assignment, which is a graph showing the native and non-native bird abundance on Mauna Kea as elevation changes, in both 1977 and 2015. Trend lines have been drawn for you through the data. How does the abundance of **native birds** change with elevation? How does the abundance of **non-native birds** change with elevation? Describe both below.

Examine Figure 2 of the data set at the end of the assignment, which is a graph showing the native and non-native bird species richness on Mauna Kea as elevation changes, in both 1977 and 2015. Trend lines have been drawn for you through the data. How does the species richness of **native birds** change with elevation? How does the species richness of **non-native birds** change with elevation? Describe both below.

Next, examine Figure 3 of the data set at the end of the assignment, which is a graph showing the native and non-native bird distribution on Mauna Kea, in both 1977 and 2015. Find i`iwi on the graph. How has the total number of i`iwi changed between 1977 and 2015?

Let's look at some raw data for these birds now. For this portion of the assignment, you will need a computer to examine two databases, and you will use a simple excel formula. The two datasets can be accessed using these links:

1977 Bird Dataset: <https://www.sciencebase.gov/catalog/item/5be52781e4b0b3fc5cf8c60b>

2015 Bird Dataset: <https://www.sciencebase.gov/catalog/item/5bee561ce4b08f163c24a170>

For each dataset, download the . file under "Attached files." Then open each file. Examine the top row where it lists the birds that were counted at each transect and station, until you locate our species of interest: "IIWI." To determine the total number of birds counted in Hawai'i in the two years of the study, scroll to the bottom of the data for "IIWI" and select an empty row below the data. In an empty square, type "=sum(" then select all the data (numbers only) in the entire column for "IIWI." Note you need the first half of the parentheses in your formula before you select your data, and be sure to close your parentheses before you hit "enter." This should give you the total number of i`iwi counted that year in all the plots. List the total number found in each year below:

1977:

2015:

What was the difference in the number of i`iwi found in 1977 vs. 2015? Please show your work, and describe the trend you see.

Next, we know that mosquitoes are a factor in the population dynamics and survival of the i'iwi. Examine Figure 4 of the data set at the end of the assignment, which is a graph showing the mosquito distribution and how it changes with elevation. While there are different periods of time during two years that are measured, as well as a model that is compared to actual numbers of trapped mosquitoes, find the highest population count and note the *general* trend that takes place in the mosquito population as elevation changes. Describe that trend below.

Question: The rate of avian malaria may increase as the numbers of mosquitoes increase and more diseased birds become hosts to the parasites, continuing the cycle of infection to healthy birds. Brainstorm some other potential reasons why we may see increased mosquitoes and/or mortality (death) in these birds, and write several (at least three) ideas below. In your answer, think about what you know about both abiotic and biotic factors, ecology, food webs, biodiversity, and global climate change. Include at least one abiotic and one biotic factor that may affect the outcome.

In order to predict what changes may occur in the future, we can begin by looking at the past. Currently, we have data collected by USGS scientists for 1977 and for 2015, looking at differences in **temperature, rainfall, and vegetation** and how they have changed during this time. Choose one of these factors to examine.

As scientists, we now know the next step of scientific inquiry is to develop a **hypothesis** that we can test. A hypothesis is a tentative explanation for an observable phenomenon (or situation) – it's a statement that offers a potential answer to a scientific question.

In this case, let's use the available data and make a hypothesis statement that answers the question, "**How will the abiotic or biotic factor that you have chosen affect the i'iwi in the future?**" Write your hypothesis below.

HYPOTHESIS:

Now that we have a hypothesis we can test, let's test it!

To do so, you'll need to continue looking at some of the data you've been given. The links to the full data set can be found here if you'd like to see it:

<https://www.sciencebase.gov/catalog/item/5b95fe4ae4b0702d0e8268c1>

Examine the data for the abiotic and biotic factor you have chosen above, and describe below how the results support, or do not support, your hypothesis.

Researchers have concluded that future global climate change will cause substantial decreases in the abundance and diversity of remaining Hawaiian bird communities. Without significant intervention many native Hawaiian species, like the scarlet 'i'iwi with its iconic curved bill, will suffer major population declines or extinction due to increasing risk from avian malaria and other factors during the 21st century.

But don't despair, there is still hope for the birds! Because these effects are unlikely to appear before mid-century, natural resource managers have time to implement conservation strategies to protect these unique species from further decimation.

Based on the data you have examined, and the knowledge you have gained through this exercise, **what advice and recommendations would you offer to natural resource managers in order to help the 'i'iwi survive?** Please write your recommendation below:

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