PATCHWORK

Using Forest Patches To Help With Forest Restoration in Palau

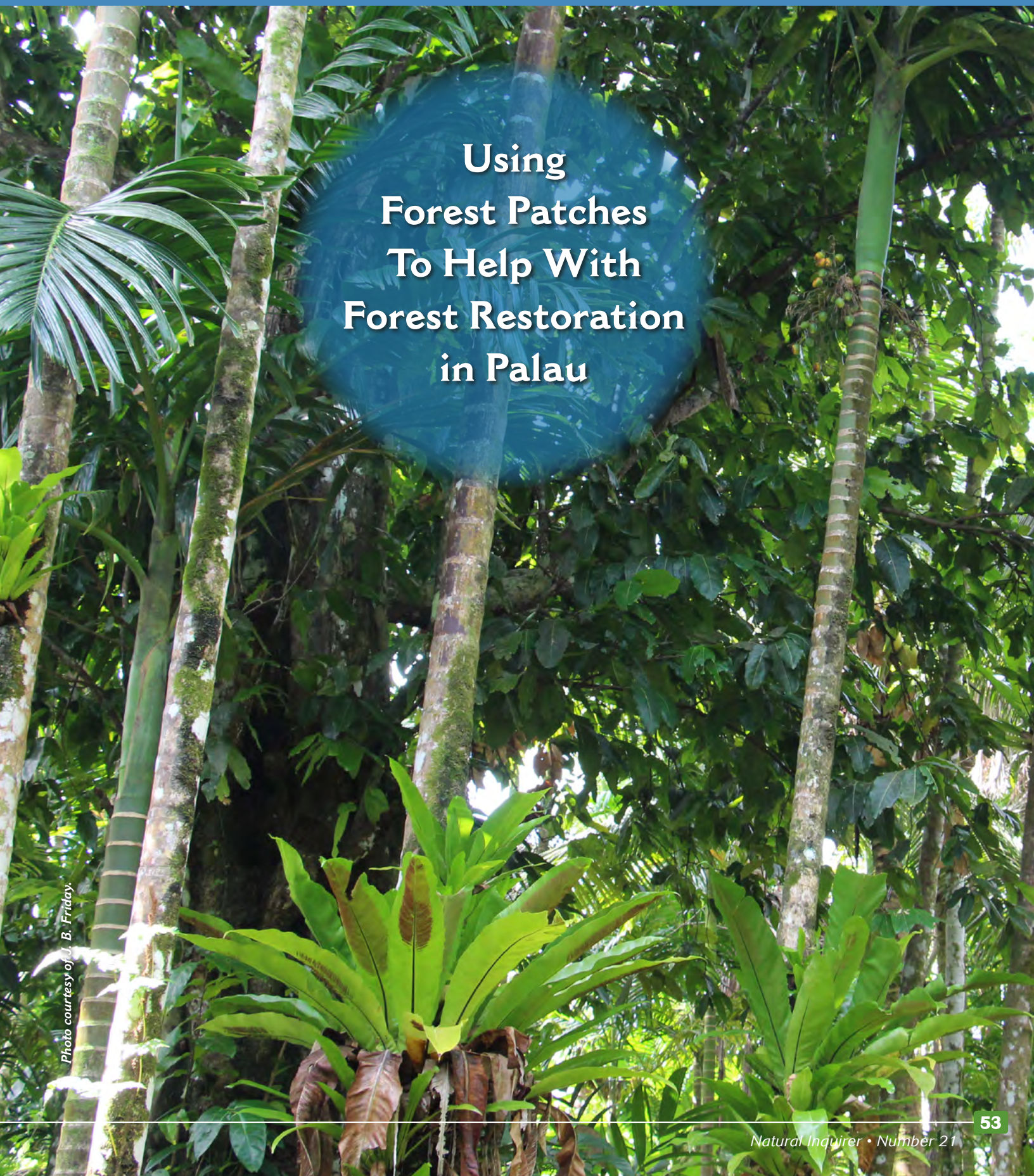


Photo courtesy of J. B. Friday.

Meet the Scientists

Photo courtesy of Julian Dendy.

◀ **Julian Dendy**, Geographic Information System (GIS) Technician/Ecologist: Overall my favorite experience related to science is the combined feeling of exhaustion, peace, and wonder after putting in a hard field day out in nature. However, the feeling most particular to doing science for me is a small excitement at having learned something new, confirming or rejecting a hunch based on field observations, or understanding a concept in a new way, after investing much time and effort collecting, organizing, and analyzing data.

USDA Forest Service photo.

◀ **Susan Cordell**, Ecologist: My favorite science experience was when I was working on my doctoral research. I had the great privilege of working in tree canopies in Hawai'i. Every day I would spend my time on a tower 50 feet above the ground asking questions about how trees do all that they need to do to survive and thrive in one place—never moving—for so long. On some days birds would visit the trees and me, but other days it was so peaceful and quiet.

USDA Forest Service photo.

◀ **Christian Giardina**, Ecologist: My favorite science experience was finding the most amazing ʻōhiʻa (**ō hē ə**) tree in the Laupāhoehoe (**la** pə **hoy** hoy) Wet Forest Unit of the Hawai'i Experimental Tropical Forest. The tree, probably 200 years ago, established as a small seedling on what must have been a truly huge tree that had fallen over. Over the centuries, this tree grew its roots down into the fallen tree while the tree began to decompose and fall away. Over time, the roots of the new tree became exposed as huge and complex pillars supporting this very large ʻōhiʻa. I have taken dozens of groups to visit with this remarkable tree, to share the remarkable story that is ʻōhiʻa, and my thoughts on why this special tree looks the way it does.

Photo courtesy of Bernice Hwang.

◀ **Bernice Hwang**, Ph.D. Candidate/ Ecologist: Some of my favorite experiences in the Pacific involved collecting arthropods from tree canopies and working on tall climate towers on Hawai'i Island. Combining some of the things I enjoy most (science and climbing), I got to enjoy rainforest views like the birds that sometimes surrounded me. Of course, it often took a lot more effort to get there than the birds (rough roads, tough hikes, difficult **logistics**) but it was always worth it! We helped to collect a lot of information that scientists used to answer interesting questions about the forests. Science can be such an adventure!

Photo courtesy of Edwin Polloi.

◀ **Edwin Polloi**, Forester: My favorite science experience includes working with nature and restoring the forests. I also enjoy seeing new plants and identifying species that have never been discovered before. I learn about the new species and how it grows. Finally, I like seeing the results of hard work, especially planting trees.

Photo courtesy of Kashgar Rengulbai.

◀ **Kashgar Rengulbai**, Forester: My favorite science experiences include working with plants and animals to gain knowledge. I like to learn about the connection between plants and animals and their ability to adapt to the environment. I enjoy meeting with various scientists and researchers and sharing information with them. When conducting scientific research in Palau, I enjoyed learning the local and scientific names of endemic and native plants of Palau, especially with new species. I also had the opportunity to learn about the Ridge to Reef system in Palau. This learning opportunity also included the connections of each ecosystem, its relationships, and interactions.

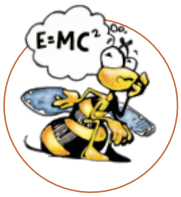
Glossary words are bold and are defined on page 65.

What Kinds of Scientists Did This Research?

Ecologist: A scientist who studies the relationship between living things and the environment.

Forester: A scientist who studies forests, or is skilled in planting, managing, and caring for trees.

Geographic Information Specialist (GIS) and Research Technician: A scientist who studies the relationship between geographic data, maps, and various other data sets.



Thinking About Science

Scientists often address problems that need a practical and inexpensive solution. In this research study, the scientists looked for a way to help with forest restoration. Forest restoration is bringing a forest back to its natural state after a disturbance like tree harvesting or fire. To study this question, the scientists developed an experimental design to test different solutions. An experimental design is a procedure to investigate a possible relationship between **variables**.

The scientists examined how a forest patch responded to four different types of treatment options. A forest patch is an area of forest identified by the scientists that could be treated to help restore the tropical forest. The scientists used the results of their experiment to make recommendations about how to restore certain forest areas.

Thinking About the Environment

Located in the tropics of the Pacific Ocean, the Pacific Islands are unique (**figure 1**). Because these islands are located close to the equator, their climate is warm all year. In this research, the scientists wanted to determine the best method for restoring tropical forests. Tropical forests are home to a wide variety of plant and animal life.

In this study, the area the researchers were studying is in the Republic of Palau (pə **laů**). The Republic of Palau is in the western Pacific Ocean and is a part of a geographic region known as Micronesia (**figure 2**). The Republic of Palau consists of 340 coral and volcanic islands. It is considered a biodiversity hotspot as it is part of the larger Micronesia-Polynesia hotspot. Learn more about biodiversity hotspots in the sidebar and on page 6.

In this study, scientists observed the number of birds that visited forest patches. Some of the **endemic** birds that were found visiting the patches were the dusky white-eye, Micronesian starling, Palau cicadabird (sə **kā** də bərd), Palau fruit dove, and morningbird (**figures 3a** and **3b**). With all the biodiversity in Palau, it is important to maintain good habitats for these plants and animals so that they can continue to flourish.

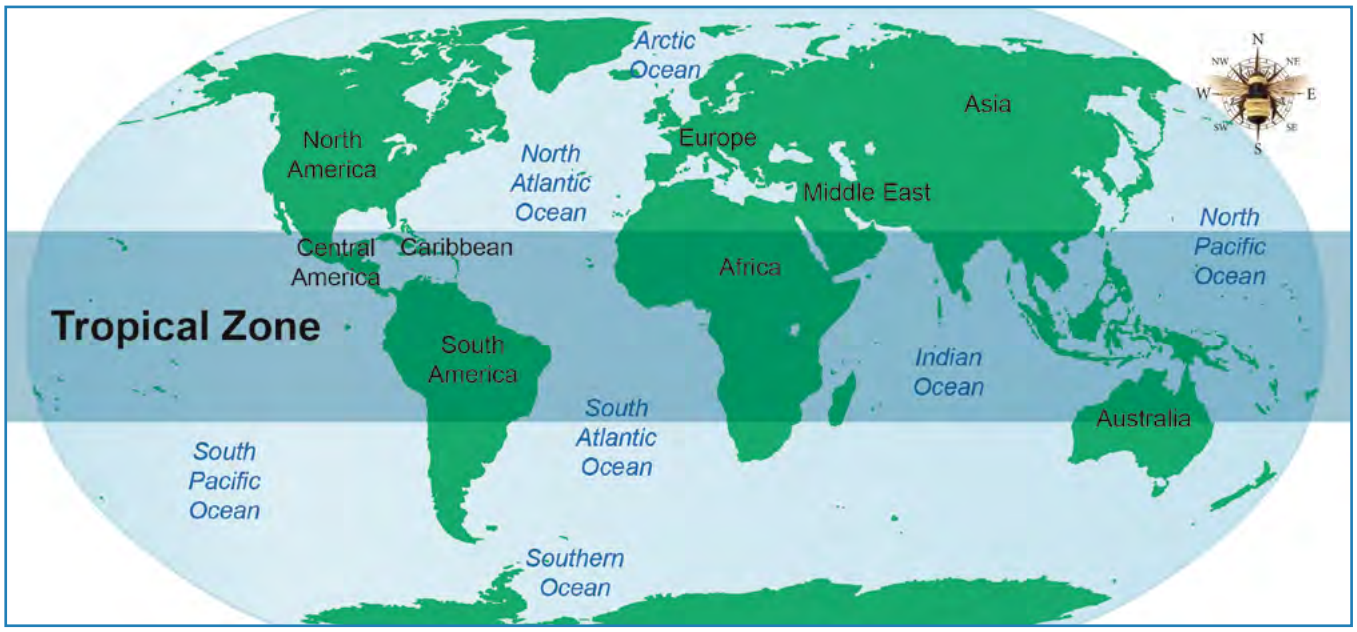


Figure 1. The tropics is an area (band of latitude) surrounding the equator between the Tropic of Cancer and the Tropic of Capricorn. FIND Outdoors map by Stephanie Pfeiffer Rossow.

Figure 2. Micronesia. FIND Outdoors map by Carey Burda.

What Is a Biodiversity Hotspot?

A biodiversity hotspot is defined as having at least 1,500 **endemic vascular** plant species and lost at least 70 percent of its primary native vegetation. While Palau by itself does not fit the definition, it is a part of the larger Micronesia-Polynesia hotspot.

Figure 3a. The dusky white-eye is an endemic bird found in the Republic of Palau. The dusky white-eye has a red eye! iStock licensed photo by Michael Stubblefield.

Figure 3b. The Micronesian starling is an endemic bird found in the Republic of Palau. iStock licensed photo by Michael Stubblefield.

Introduction

Babeldaob (**bä bəl daůb**) is the largest island of the Republic of Palau (**figure 4**). Babeldaob contains one of the largest intact areas of native tropical lowland rainforest in the tropical Pacific. It is known for its great abundance of ecological diversity and is home to Lake Ngardok (**ə gär däk**) Nature Reserve. The reserve covers 650 hectares (ha) of land and contains Lake Ngardok (**figures 5a–5c**).

Lake Ngardok is the largest freshwater lake in Micronesia and is considered a local hotspot for endemic plant and animal species (**figure 6**). Endemic species are native to a specific area and found nowhere else on Earth. Endemic species are often **endangered** and are an important component of biological diversity.

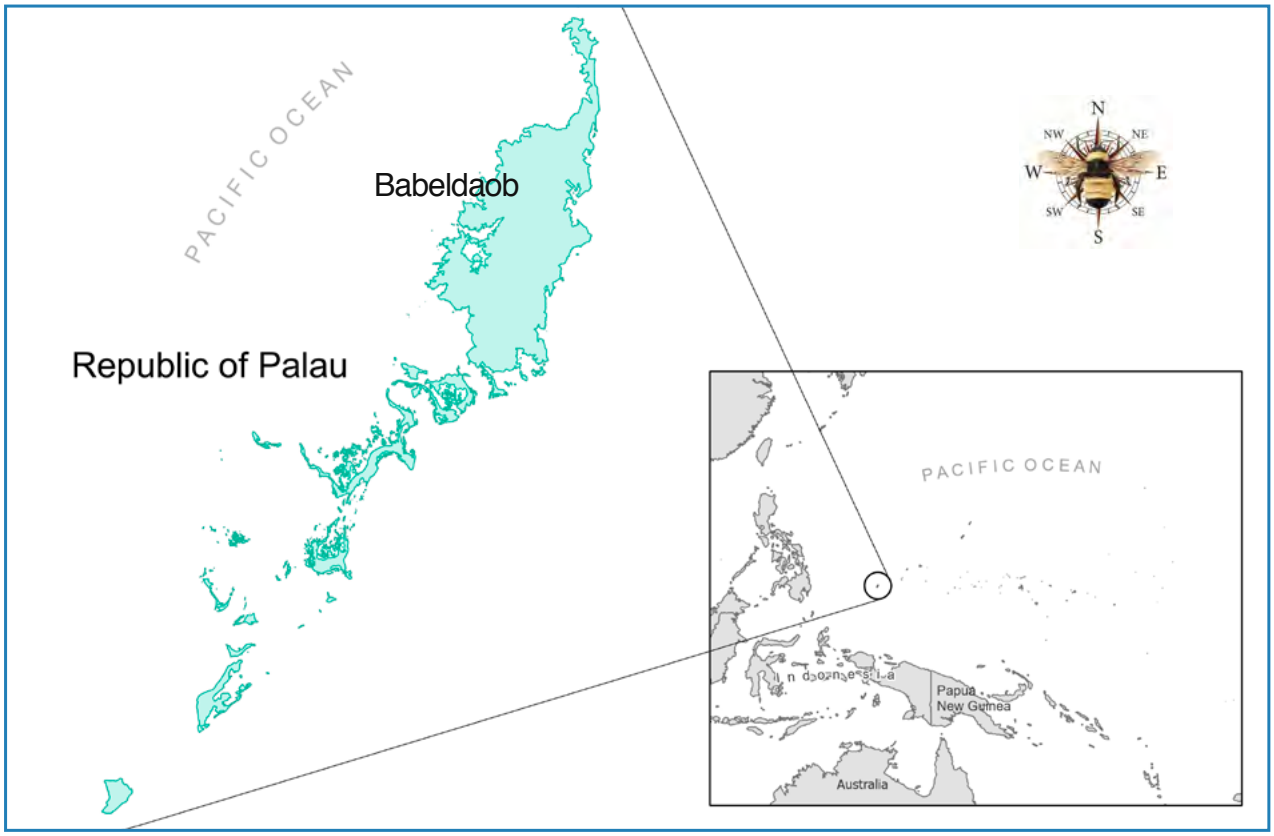


Figure 4. The Republic of Palau. FIND Outdoors map by Carey Burda.

Figures 5a–5c. Lake Ngardok Nature Preserve. Smithsonian ForestGEO photos.

Parts of the Lake Ngardok Nature Reserve were cleared for agriculture in the early 1900s and then abandoned after World War II (1945). Vegetation that grew in this area was periodically managed with fire until the reserve was created in 1997. The management plan for the reserve called for restoring the soils and forest. Attempts were made to do this by planting *Acacia auriculiformis* (**ə kā shə är ik yə lə fȯr məs**), a nonnative tree that was meant to help improve the quality of the soil (**figure 7**). However, this strategy failed because almost all the trees died or had stunted growth. Therefore, the scientists in this study were interested in figuring out what kind of treatment would lead to the best outcomes for the restoration of native forest here.

Figure 6. Lake Ngardok is the largest freshwater lake in Micronesia. Smithsonian ForestGEO photo.

Figure 7. *Acacia auriculiformis* is a non-native tree that was unsuccessfully used to help improve the quality of the soil in Palau. Smithsonian ForestGEO photo.

Number Crunches

1 hectare of land equals 2.47 acres.

- How many acres of land are in the Lake Ngardok Nature Reserve?
- How many years has it been since the reserve was created?

Reflection Section

- In your own words and in the form of a question, state what the scientists wanted to learn.
- Based on what you read in the Thinking About Environment section and the Introduction, do you think it is important to try to restore a tropical forest that has been degraded? Why or why not?

Methods

The scientists identified 32 forest patches (**figure 8**). The patches varied in size from 4 to 275 square meters (m^2). The scientists applied four different treatments for forest restoration (**table 1**) and monitored these patches for 3 years. Each of the treatments were low cost and easy to implement.

The scientists examined six ecological indicators to determine the effectiveness of the patch treatments. Ecological indicators enable scientists to gauge how the environment is responding to a certain treatment or a changing condition.

The scientists recorded a variety of data including the number of patch visits by birds and flying foxes, the number of flowering and fruiting plants, and the number and diversity of seedlings as well as the data for the six ecological indicators (**figures 9, 10,** and **table 2**, pages 61 and 62). Patch visits were recorded twice a day for 7 days, twice a month, from July to December 2010. The scientists recorded data from 6 a.m. to 8 a.m. and 4 p.m. to 6 p.m. The scientists used computer software to help them **analyze** the data they gathered.

Figure 8. Looking out over the forest patch areas in Lake Ngardok Nature Preserve. Smithsonian ForestGEO photo.

Table 1. The scientists examined four different treatments for forest restoration.

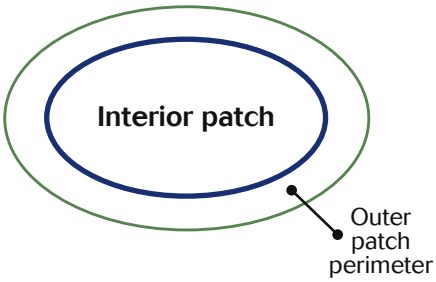
Treatment	Treatment description
Interior patch fertilization	The inside of the patch received fertilization.
Outer patch **perimeter** mulching 	In the patch, but on the outside edge, mulching occurred (see diagram). Mulch was produced from shredded branches and leaves pruned from ***Acacia auriculiformis*** trees outside of the study area. The mulch was applied by hand to a depth of 2 centimeters (cm) and width of 1 meter (m).
Outer patch perimeter trimming	The **herbaceous** vegetation was trimmed with a machete to ground level. This trimming was done in a 1 m band surrounding the patch.
Planting native tree seedlings	Seedlings of five common native tree species were planted 1 m apart along the perimeter of the interior patch.

Figure 9. Mr. Dendy taking measurements in Lake Ngardok Nature Preserve. ForestGEO photo.

Figure 10. Flying foxes are large, fruit-eating bats. Adobe Stock licensed photo by Viacheslav.

Table 2. The scientists examined data regarding six ecological indicators.

Ecological indicators
1. Amount that the patch expanded in area over time
2. Growth rates of naturally occurring native tree saplings in patch perimeters
3. Growth rates of native tree seedlings planted in outer patch perimeters
4. Density and species diversity of naturally established tree seedlings in patch perimeters
5. Fruit and flower production of native patch tree species
6. Patch visitation frequency by birds and flying foxes

Reflection Section

- Look at table 1 on page 61. Notice how the mulch was applied by hand 2 cm deep and 1 m wide. Why do you think the scientists applied mulch by hand instead of using a machine?
- Notice that the scientists recorded patch visit data in the morning and in the late afternoon/early evening. Why do you think they chose those time periods for data collection?

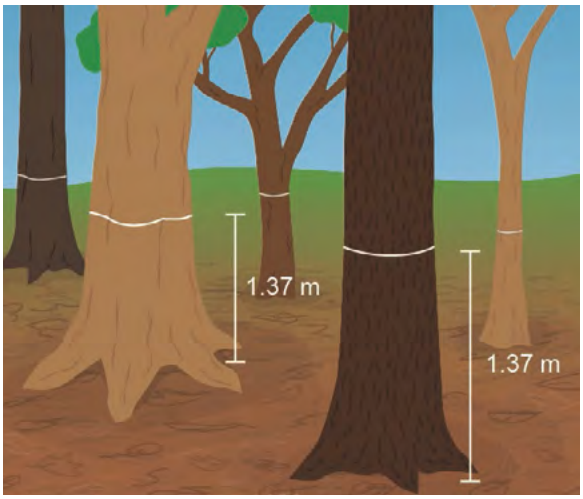
Findings

The scientists found that the diversity of tree species, the height of the tallest patch tree, and **basal area** of the trees all increased with the size of the patch. The application of fertilizer helped accelerate patch expansion. Four years after establishing the forest patch sites, the fertilized patches had expanded about five times more than nonfertilized forest patches. Fertilizer use also increased flower, fruit, and new tree leaf production. In fertilized patches, more tree species per patch flowered, fruited, and had new leaves than the nonfertilized patches. Fertilizer also helped increase the growth of naturally occurring **saplings**.

The scientists also found that the diversity of bird species increased with the size of the patch. Fertilized forest patches had an increase in bird visitation. The three species that visited the most were dusky white-eye, Micronesian starling, and the Palau cicadabird. Eight of the species on the list are endemic to Palau (**table 3**). Additionally, the Palau flying fox visited only one patch, but had far more flyovers than any other species in the study. A flyover occurs when an animal flies over but does not stop at the forest patch. These are important to forest restoration because birds and bats can disperse seeds during flyovers when they **defecate** or otherwise drop a seed. These seeds may then establish themselves and grow in that area.

What Is Basal Area?

Basal area of a tree is defined as the cross-sectional area (in square meters (m) or square feet) of a single tree at breast height, or 1.37 m (4.5 feet) above ground. The diameter of a tree at 1.37 m above the ground is called diameter at breast height (DBH).



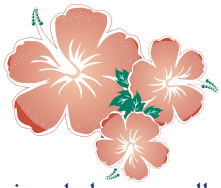
FIND Outdoors illustration by Liz Sisk.

Table 3. Animal visits to the forest patches from July to December 2010. Those species marked with an asterisk (*) are endemic to Palau.

Common name for species	Number of visits
*Dusky white-eye	1,017
Micronesian starling	260
*Palau cicadabird	163
Micronesian myzomela (**mī** krə **nē** zhən **mī** zə **mə** lä)	109
*Palau flycatcher	95
*Palau fantail	75
Citrine white-eye	38
*Palau fruit dove	31
*Rusty-capped kingfisher	8
Gray nightjar	2
*Morningbird	2
*Palau bush warbler	1
Palau flying fox	1
White tern	1
Rats	6
Grand Total	**1,809**

Reflection Section

- Look at table 3. What do you notice about the dusky white-eye? What percentage of the visits did the dusky white-eye make to the patch compared to all the other visitors?
- Based on what you read in the "Findings," what actions would you suggest would help with the restoration of the tropical forests in Palau?



Discussion

The scientists found that 6 of the top 10 patch visits were made by species that are endemic to Palau. Scientists believe that this may indicate that endemic species play an important role in how plant communities interact and restore landscapes. Scientists also found that fertilizer application had a positive effect on forest patch trees and that effect extended all the way to the exterior edge of the patches.

The scientists determined that small, periodic applications of fertilizer can increase the rate of forest patch expansion and lead to greater visitation by native or endemic birds. This small, periodic application of fertilizer also avoids potentially damaging nutrient runoff from fertilizers. Sometimes, too much fertilizer runoff going into waterways can cause problems for plants and animals. By limiting the amount of fertilizer used per application, this problem is reduced.

Reflection Section

- After having read this article, what is the most interesting thing you learned? Why?
- The scientists discovered that small applications of fertilizer helped to restore forest patches. Why do you think fertilizer is helpful to the growth of forest patches?

Adapted from Dendy, J.; Cordell, S.; Giardina, C.P.; Hwang, B.; Polloi, E.; Rengulbai, K. 2015. The role of remnant forest patches for habitat restoration in degraded areas of Palau. Restoration Ecology. 23(6): 872–881.

Glossary

basal area (**bā** zəl): The area of a breast-high cross section of a tree or of all the trees in a stand. Typically measured at 1.37 m (4.5 ft) from the ground.

defecate (**de** fi kāt): To discharge feces from the bowels (to poop).

ecology (e **kä** lə jē): The study of the interactions of living things with one another and with their environment.

ecosystem (**ē** kō sis təm): Community of plants and animal species interacting with one another and with the nonliving environment.

endangered (in **dān** jərd): Species whose continued existence is in danger.

endemic (en **de** mik): Found especially and often only in a certain locality or region.

herbaceous ((h)ər **bā** shəs): Of, relating to, or having the characteristics of an herb.

invasive species (in **vā** siv **spē** shēz): Any plant, animal, or organism that is not native to the ecosystem it is in, and is likely to cause harm to the environment, the economy, or human health.

logisitics (lō **ji** stiks): The handling of the details of an operation.

migratory (**mī** grə tȯr ē): Having a characteristic of moving from one place to another on a periodic basis.

perimeter (pə **ri** mə tər): A line or strip bounding or protecting an area.

sapling (**sa** pliŋ): A young tree; specifically, one not over 4 inches (about 10 cm) in diameter at breast height of 1.37 m (4.5 ft).

*Accented syllables are in **bold**. Marks and definitions are from http://www.merriam-webster.com.*
Definitions are limited to the word's use in the article.

Time Needed

3–4 class periods

Materials

- Nature inventory sheet
- Clipboard
- Pencil
- Stopwatch or timer
- Poster paper
- Markers
- Research materials (internet, books from the library, etc.)

In this FACTivity, you will explore natural areas near your school or home. You will come up with a plan to help support natural vegetation and wildlife in the area.

Adobe Stock photo.

Methods

You are going to sit outside, in one place, for 10 minutes. Your job is to be a nature observer. You should be as quiet as possible during your 10-minute observation so you can see and hear as much as possible. Do a general observation of everything for 8 minutes, then a specific observation of one plant or animal for 2 minutes. You will write down things you observe, hear, and smell on your nature inventory sheet.

After 10 minutes, your teacher will lead a class discussion on what kinds of things were observed during the 10 minutes.

Next, you will research your native habitat. Find out what kinds of animals typically live in your area. What kind of plants are common? Do any endangered or threatened species live in your area?

Your teacher will divide you into pairs or small groups. Your task will be to create a plan with at least three things that people can do to help support the natural vegetation and wildlife in your area. For example, is there a plant that could be planted to help? What kind of plant is it? How frequently would it need to be planted?

Create a poster with the three things people can do and hang these posters in your school.

Name _____

NATURE INVENTORY SHEET

Pick a place to sit quietly for 8 minutes. Write down the following information.

What do you see?	What do you hear?	What do you smell?

Pick one of the animals or plants that you see and observe it closely for 2 minutes. Write down your observations about it and sketch it. For example, if you are observing a bird for 2 minutes, draw it, then write down what it looks like, what sounds it makes, what movements it does, etc.

Sketch of my plant or animal

Observations about my plant or animal

Natural Inquirer Connections

You may want to reference these *Natural Inquirer* resources for additional information and FACTivities:

- Hawai'i/Pacific Islands edition—"Treasure Islands: Hawaiian Kipuka and the Future of Native Hawaiian Birds"
- Olympic Winter Games edition—"Goldifinch and the Three Scales: Investigating Songbird Habitats Near Rivers"
- Tropical edition—"The Trees Have Gone Batty! How Bat Scat Helped Restore a Tropical Forest"

These resources, along with others, can be found at https://www.naturalinquirer.org/all-issues.html.

Project Learning Tree®

If you are a Project Learning Tree educator, you may use "Watch on Wetlands" or "Soil Stories" as an additional resource.

Web Resources

Smithsonian-ForestGEO: Ngardok
https://forestgeo.si.edu/sites/palau/ngardok

CIA World Factbook: Palau
https://www.cia.gov/the-world-factbook/countries/palau/

PBS: Palau, Paradise of the Pacific
http://www.pbs.org/edens/palau/p_sea_text.htm

NOAA: Coral Reef Information System, Republic of Palau
https://www.coris.noaa.gov/portals/palau.html

Smithsonian: Secret Orchids of Palau
http://sercblog.si.edu/the-secret-orchids-of-palau/

Forest Service: Institute of Pacific Islands Forestry
https://www.fs.fed.us/psw/programs/ipif/