Where Are the Climate Change Superheroes?

Systems Thinking and Climate Activism in the Children's Eternal Rainforest

By Eric Fishman

At the end of our year studying climate change, two of my 4th-grade students sat down together and wrote a prose poem from the perspective of the resplendent quetzal, a Central American bird threatened by global warming. One stanza, in particular, stuck with me:

> *My Uncle Frederick said that climate change was a terrible thing. It would ruin our homes and flush the avocado trees into the ocean like a toilet flushing its contents. Then us quetzals would starve and die out. Before the conversation, I didn't believe any of it. But afterwards I knew it was real. And I was in big trouble. With your help, we can stop climate change and be superheroes.*

This stanza struck me as a fascinating exploration of how our choices as educators can shape the frameworks our students have for understanding climate change and climate justice. Uncle Frederick aimed to alarm his niece or nephew with a provocative simile. He emphasized the potentially disastrous consequences of climate change. The young quetzal was not too depressed by the speech and in fact left feeling empowered to "stop climate change." But did the young quetzal have the tools and knowledge necessary to effect real change? A superhero is nothing without their superpowers.

Throughout my year of teaching about climate change from scientific, social, and literary angles with my 3rd- and 4th-grade students, I wrestled with the same conundrums facing Uncle Frederick. How do we teach students about the complex realities of climate change without leaving them hopeless? And what kinds of knowledge do they need in order to be empowered advocates for climate justice?

Moving Away from Abstract Causes and Effects

When I designed this unit, I was teaching at a K–8 independent school in Winchester, Massachusetts, that serves a gifted and "twice-exceptional" (gifted students who also have special needs) student body. Because of the structure of the school, each year I'm able to invent a theme-based curriculum from scratch. For the 2016–17 school year, I chose climate change: I felt the urgency of educating students about this topic and I was excited by the mosaic of subjects that fall under the larger climate change umbrella.

Olivia Wise

I entered the year believing I would spend much of my instructional time helping students investigate the basic science and social factors behind climate change. With a firm understanding of human influence on natural systems, I reasoned, my students could move on to thinking about solutions. I designed mini-labs surrounding the science of heat and light, and students worked in groups to create artistic representations of fragile balances that were being thrown off, such as melting glaciers and disruptions in El Niño and La Niña. However, by the end of October I began to realize a shift was necessary.

Two major problems arose. First, while some students identified with the subject they had researched for the artistic modeling project, others had not been emotionally engaged. The abstract concepts of oceanic currents and sheet ice were not the easiest to identify with. While students could intellectually process that climate change was "bad," they didn't feel an emotional stake in the issue. Also, these lessons had not left students feeling empowered. During one of our early discussions about the greenhouse effect, Sophie exclaimed, "Why are we even learning about this if there's nothing we can do about it?" Disengaged and depressed was not what I was aiming for.

For children — and really, for all people — biodiversity manifests itself primarily through the sounds, sights, and smells of the natural world.

I thought that my students needed a more concrete angle to understand the effects of climate change and the possibilities for climate justice. I decided we should focus on biodiversity, with hopes that thinking about the interaction of plants and animals with climate change could leverage my students' strong empathy for the natural world. In addition, biodiversity and ecosystems inherently lend themselves to systems thinking.

The challenge of thinking from a systems level is particularly acute for 3rd- and 4th-grade students, many of whom have just recently begun to develop their capacity for abstract reasoning.

Throughout the year, we had pushed ourselves to think about concepts such as interdependencies (How does an international climate agreement affect the ability of people living in poverty to purchase air conditioners?) and feedback loops (How do jellyfish contribute to climate change, and how might climate change lead to surging jellyfish populations?). I hoped to solidify these kinds of thinking through a more extended unit.

The Resplendent Quetzal

I wanted my students to begin our study of biodiversity with an emotional connection, so the first thing we did was go to a local park. Students created "sound maps" of the natural and human-made noises around them, rubbed leaves between their hands and shared the smells with each other, and searched for interactions between different species. For children — and really, for all people — biodiversity manifests itself primarily through the sounds, sights, and smells of the natural world.

Next, we considered the link between biodiversity and the resiliency of ecosystems. Adapting an activity from Kate Lyman in *A People's Curriculum for the Earth*, I helped my students create a physical model of a food web (using string) from two different ecosystems: one that was biodiverse, and one that was not. The same species was wiped out in each of them. While the biodiverse ecosystem stayed relatively stable, the other ecosystem literally fell apart.

With these foundations — emotional and intellectual — I felt my students were ready to investigate a more complex situation: the resplendent quetzal. The previous summer, I attended a course in Monteverde, Costa Rica, that focused on the interaction of people and the biology of the cloud forest. In the cloud forest, the effects of climate change are already being viscerally felt. Torrential rainstorms regularly damage roads, bridges, and houses. Key crops such as coffee and chocolate have become more difficult to grow and more susceptible to diseases. And the astonishing biodiversity of the cloud forest is threatened. These were complex systems that required thoughtful solutions.

I spoke with local guides and ecologists to find a representative example to bring back to my students. I knew I wanted my students to investigate how the biodiversity of the cloud forest was coming under threat due to climate change. One of the guides suggested that I look into the resplendent quetzal.

The resplendent quetzal is endemic to only narrow swaths of Central America. This magnificent bird played an important role in various Mesoamerican mythologies. It is the national bird of Guatemala and is considered a symbol of liberty in other Central American countries. The quetzal is also predicted to be one of the species most threatened by climate change. Adult quetzals are mainly fruit eaters, particularly eating various species of wild avocado. In Monteverde, for example, quetzals migrate through five different life zones, up and down in elevation, following the fruiting of different patches of avocado trees as they ripen at different times.

As the climate changes, the zones that the avocado can live in are moving up in elevation. The avocado tree is dependent on the quetzal and only a few other species of birds for seed dispersal because its large seed (pit) can be consumed only by birds with specialized adaptations. Unfortunately, quetzals and other fruit-eating birds are not moving the seeds of the avocado to these new zones: There are no avocado trees there already, so there is no incentive for the birds to go there. With fewer avocado trees remaining, there is less available food for the quetzal. To add to the quetzal's woes, the toucan, which used to live primarily in lower elevation zones, has been moving up into the quetzal's territory as temperatures increase — and sometimes eating the quetzal's eggs. Also, much of the quetzal's habitat has been deforested for farmland. The narrowing of the range of the wild avocado may lead to the narrowing of the range and the possible extinction of the resplendent quetzal.

In order to model this system and help students consider possible solutions, I developed a board game: *The Quetzal Conundrum*.

Introducing the Game

I began by introducing my students to the location they would be playing in: The Children's Eternal Rainforest. I showed them Costa Rica on a world map and explained, "Today, we'll be exploring one of the most biodiverse places on the planet: the rainforests of Costa Rica. Climate change is already having lots of different impacts here. We're going to be looking at some of these impacts today, and thinking about what solutions there might be."

Next, I shared the story of how the Children's Eternal Rainforest was created. This rainforest's name has an empowering origin story: One elementary school class in Sweden inspired a worldwide student fundraising drive that ended up raising more than $2 million toward the protection of thousands of hectares in the Costa Rican cloud forest. The students definitely responded well to this story, as well as to the photos I showed them of my time there. "Wait — kids raised millions of dollars for this?" exclaimed Marta.

This rainforest's name has an empowering origin story: One elementary school class in Sweden inspired a worldwide student fundraising drive that ended up raising more than $2 million toward the protection of thousands of hectares in the Costa Rican cloud forest.

After this, I introduced the relationship we would be examining: the connection between the resplendent quetzal and the wild avocado. I played a video of the quetzal eating a wild avocado, digesting it, and then — to the astonishment of the students — vomiting up the pit. "Play that part again!" they insisted. "This is one of the only ways the wild avocado can move its seeds around," I explained. "It used to be eaten by large animals that died out during the last ice age. Now, the quetzal has a specific adaptation that allows it to eat such a big fruit." I showed the class a picture of the wild avocado pit next to the skull of a quetzal. "The pit is bigger than the skull!" exclaimed Joseph.

Finally, I introduced the premise and logistics of the game. I informed the students that they would be playing in pairs and half of them would be playing wild avocados and half would be playing resplendent quetzals. I let them know that they would be able to choose which they would play, but that we needed to ensure that we had enough of each role. Anticipating that there might be more kids who wanted to play the quetzal than the avocado, I first asked for volunteers for the avocado trees. "Who wants to be the source of life and nourishment for this ecosystem?" This drew enough volunteers.

Once the students had their roles, I asked the class to gather around the game board so I could model how the game worked. "You'll be playing the game in three rounds," I explained. "In each round, you will be playing at a different time period. The first round will take place in 2017, the second in 2025, and the last in 2050. So do you think that you'll actually be playing as the exact same birds or the exact same trees each round?" I made sure that the students understood that in rounds 2 and 3, they would be playing as the descendants of their "characters," not the original ones.

"Your goal for this game is simple: Work together with your partner to survive the changing climate."

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I showed the game board to the students. The background is a satellite image of the Children's Eternal Rainforest with four "life zones" drawn as concentric circles. The central life zone is the highest elevation, and the outermost life zone has the lowest elevation. "Will it get colder or warmer as we move up the mountain?" I asked. For students who hesitated, I showed a couple photos from Costa Rica, one of the windy, foggy top of a mountain, and one of the hot, humid lower elevation forest.

I helped my students notice that each life zone contained a temperature marking for 2017 (round 1), 2025 (round 2), and 2050 (round 3). These temperatures increased for rounds two and three as a result of climate change. For the sake of easy game play, the temperature increases are greater than what are actually predicted by climate scientists, and I explained this to the students as well.

One of my students also noticed the red "T" marked under the temperature readings for certain zones for certain years. I clarified that this "T" indicated that there were toucans living in that life zone for that round.

I had a student read out the goals for the quetzal. "Each of your three quetzal game pieces needs to eat from a fruiting avocado tree each round in order for its descendants to survive to the next round." Next, another student read out the goals for the wild avocado. "In order to survive to the next round, a quetzal must have dropped your seeds in a life zone with a suitable temperature."

Each rule of the game is designed to represent a biological reality. For example, the wild avocados can only live in life zones that have a certain temperature range. The quetzals need to be placed in the same life zone as an avocado tree because they need something to eat. Avocado trees can't walk on their own, so they can be placed only in life zones where there was a quetzal in the previous round (to drop their seeds).

(For a detailed overview of game play, consult the lesson plan in the Resources section at the end of the article.)

"The Game Is Rigged!"

For each round of the game, pairs of students place their pieces strategically, then take turns rolling a die to simulate the fruiting of avocado trees and other events. Based on what happens in the round, their pieces either survive to the next round or are removed from the game. The goal is to work together to survive all three rounds.

After I demonstrated a round, the students went off to play the game, and I circulated to clarify the instructions. Whenever possible, I avoided answering the questions myself, and instead pointed students to the relevant part of their character role sheets. I reminded students to record their surviving pieces before and after each round.

Students were highly engaged in their roles. One avocado player was imitating a tree's branches with his arms as he played, and one quetzal "flew" over to her work spot in the classroom, flapping her arms.

Every time someone rolled a six, opening up the quetzals to an attack from the toucans, I heard a collective groan. Students cheered each time their pieces survived a round. One group even did a little dance after all their pieces made it through the first round.

I heard partners scheming together about where to place their pieces between rounds. Even Sasha and Leo, two of my most competitive students, had channeled this competition into a remarkably collaborative effort to survive climate change:

"I'm going to place most of my trees in life zone four," suggested Sasha.

"Wait, there are toucans there. Let's avoid that zone," countered Leo.

"OK, good idea," Sasha agreed.

After about 15 minutes, the students began to move into the last round of the game, which represents the year 2050.

If the students play the game correctly, there is almost no way their quetzals will survive through the last round. The number of available life zones for trees shrinks, the toucans encroach on the quetzals' territory, and in the end, there's almost nothing left for the quetzals to eat.

As I circulated, I reminded the students that they were acting like ecologists, trying to observe what was happening so we could help find solutions. As climate change took its toll on their quetzals and avocado trees, I wanted to make sure the students were able to step back a bit and observe without getting too upset about losing.

I watched as Tom and Simon finished the game. They were struggling to place their avocado trees in the two life zones remaining. Simon said, "Let's put one at the top of the mountain." Tom countered, "We can't — there hasn't been a quetzal there ever!" Simon, looking peeved, glanced up at me and muttered, "The game is rigged!"

Well, yes, the game is rigged. This is, however, precisely the point. Given current climate estimates, the quetzal will most likely go extinct — unless we intervene.

Later, when the group gathered together to debrief, Simon complained: "What is the point of playing the game in the first place if there's no way to win?"

"What do you think?" I asked the class.

"You want to depress us!" Ben suggested.

I chuckled. "That's one possibility. Are there any others?"

"Well, maybe we can do something about it now that we know what's happening," Tom offered.

"Precisely! Let's take a look and see if we can figure out exactly what was going on here. We can't help if we don't know what's happening."

I reminded the students that they were acting like ecologists, trying to observe what was happening so we could help find solutions.

Immediately following the game, each pair used a reflection sheet to analyze what happened to the quetzals and avocados. Now, I guided the class through a reflection on how the effects of climate change they observed in the game were interconnected. As a group, we tried to coalesce some of these elements together into a systems diagram:

"Why couldn't the avocado tree keep moving up the mountain as the climate warmed?" I asked.

"The quetzal wasn't moving its seeds there!" Simon responded.

"OK. So there was a problem with seed movement."

I wrote "seed movement" on the board.

"OK, what happened next?"

"The avocado trees started dying because they didn't have any place to go!" a student responded. So I put on the board:

seed movement > avocado population

"Then what?"

"The quetzals didn't have enough food, so they starved."

seed movement > avocado population > quetzal population

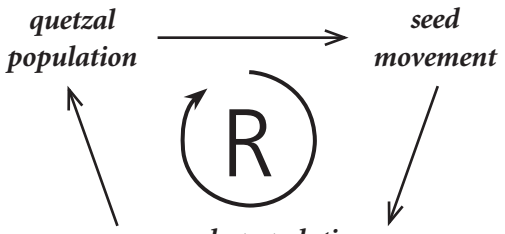
"What impact would that have on the avocado trees?"

"There would be even fewer quetzals to move the seeds!"

seed movement > avocado population > quetzal population > seed movement

"Wait," Sophie interjected. "Isn't this becoming a loop?"

This was the magic moment where a system emerged from the "heap" of disparate parts. The students had discovered the reinforcing loop:



***The R shows that the cycle reinforces itself.**

"You just made an essential observation," I informed the students. "This loop is going to reinforce itself, or get stronger and stronger as it goes along. Right now, this reinforcing loop is resulting in dramatic decreases in all three: seed movement, quetzal population, and avocado population. Let's imagine that we live in Monteverde. We could be dairy farmers; we could be ecologists; we could just be concerned citizens. We've discovered this reinforcing loop. What could we do about it?"

"Save the quetzals!" said Sophie.

"Yes, but how? Let's look at our systems diagram. How might we intervene?"

"Well," Tommy suggested, "if we stop climate change, the avocado trees won't have to move."

"That'd be like rewriting the rules of the game!" Sophie added.

"That sounds like a powerful potential solution," I responded. "Does anyone remember when we simulated companies competing to produce products earlier in the year? We tried to 'rewrite' the rules of that game too, as consumers, factory owners, and government officials." (This was an adaptation of Bill Bigelow's "Thingamabob Game".) "What kind of activism could we do here?" I asked my class.

"Write to people in government about renewable energy!" suggested one student. Another added, "Or try to get people to boycott polluting companies."

"Those are great ideas," I responded. "We should definitely do both of those things, in addition to working to reduce our own carbon footprint. Let's talk about how we could write letters to some of these stakeholders. In addition to this activism, considering what we just learned from the game about this specific ecosystem, are there any other steps we could take to help protect the quetzal and avocado from the impacts of climate change? Where in the systems diagram should we look?"

Pretty quickly, the students zoomed in on "seed movement." They determined that we should try and help with seed dispersal for the avocado. "We could go and plant the avocado trees at the top of the mountain!"

"OK, that's a great idea. Let's take a look at where we might want to plant these," I replied. I pulled up Google Maps on the projector and searched for the satellite image of Monteverde.

"What's all of that brown and light green land?" I asked the class. They weren't sure, so I zoomed in more. Eventually, they were able to identify that it was farmland.

"There are lots of dairy farms in Monteverde," I explained. "This is one of the most important ways to make money for people who live in this area. Might this raise any issues, though?"

"You can't plant trees on someone else's land!" Sophie replied.

"Exactly. Does anyone have any ideas as to how we could address this?" "You could order people to plant seeds," Marcel suggested.

Brian countered, "You can't force people to do that! They'd have to want to do it first."

Rachel suggested, "So I guess we'd have to teach them about why it would be helpful to them, too?"

Students were quickly able to establish that people's emotional connection to animals and plants would be important in inspiring them to combat climate change. I pushed them to think

about how this game might help us use logic and ethics as well, to convince people about the realities of climate change.

The Quetzal Conundrum was one of the major foundations that led to the students' writing persuasive letters to public officials. I gave them choice over what they would write about, and several students dove immediately into further research about reforestation. They found local species that were threatened by climate change and habitat degradation and explained their research in detailed letters to the Massachusetts governor and their senators and representatives.

Later on in the year, students were able to research a local species (alewife herring), and how climate change and hydroelectric dams were threatening to push them into endangered status. Some parents were able to take students to the local Mystic River, where they investigated the new herring ladder that had been installed to allow fish to migrate past the dam. All the students took part in an online citizen science project to help ecologists determine the impact of this intervention on the herring populations.

Overall, this board game was effective in enabling students to move from the abstract (a biological system in Costa Rica) to the concrete: taking action in their own communities. From a board game intervention, they can move into real-life interventions.

In their poem about Uncle Frederick, my students issued a call for the next genzeration of climate change "superheroes." As educators, we have a responsibility to answer this call. Even young students need to confront the real, complex systems that are being impacted by climate change. Then, they need opportunities to intervene in these systems. All of our students deserve opportunities to grow their climate justice superpowers.

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The Quetzal Conundrum

Game Instructions and Handouts

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*** A video overview of gameplay is available at bit.ly/QuetzalConundrumVideo.*
*Highly recommend you watch this!***

NB: Instructions and materials for an extension game—in which students act as dairy farmers and make decisions about whether or not to reforest their land—can be found at bit.ly/QuetzalConundrumExtension

The Quetzal Conundrum

Activity Overview

Guiding questions

How are the fates of the quetzal and wild avocado linked?

Why are these species threatened by climate change, and how can we intervene?

Learning objectives

This game could be appropriate for students in grades 4-8, or for high-capacity 3rd graders.

This lesson will allow students to experience and analyze:

1. the ways in which climate change can threaten species.
2. how changes in the population of one species can have profound effects on other species.
3. the complexities of climate change activism in the context of small communities.

After Game 1, students should be able to:

1. articulate why climate change is threatening the quetzal, and how the quetzal's fate is also linked to the fate of the avocado.
2. propose ideas to mitigate the threats of climate change on the quetzal (and hypothesize how they might be able to engage in activism to help make these ideas a reality).

Prerequisite knowledge

Students should have already learned about the basics of climate change, biodiversity, and ecosystems, as well as how biodiversity affects ecosystem resiliency.

Prerequisite vocabulary: resiliency, biodiversity, life zones, reforestation

Time

1 hour and 15 min.

Materials

All of the materials below, with the exception of the dice and the Expo markers, are available as printouts.

Students should be in groups of 2-3.

For each group:

- ❑ 1 Children's Eternal Rainforest game board
  - — There is overlap on the two pages of the printout. You have to combine them into one board.
  - — Preferably these would be laminated, so students can "color over" the temperatures that aren't being used with Expo marker
- ❑ 1 Expo marker
- ❑ 1 copy of the species-tracking data sheets
- ❑ 1 copy of the reflection questions
- ❑ Quetzal and avocado game pieces, printed *double-sided* on cardstock and cut out
- ❑ 1 six-sided die

For each student:

- ❑ Game rules. At least 1 quetzal player and 1 avocado player per group.

Lesson Sequence

Part 1: Introduction to the Resplendent Quetzal (10 min.)

Show students the following video of the quetzal eating a wild avocado:

http://viewpure.com/FuYWo66xDwI?start=0&end=0

Quick discussion: What do you notice about the quetzal? Allow students to wonder about the bird.

Introduce the *place* this simulation will take place in: the Children's Eternal Rainforest of Monteverde, Costa Rica. Quick background on this reserve:

https://publish.illinois.edu/wnorris2/

http://viewpure.com/ZQ4DXjZZgrc?start=0&end=0

(Note that there are some somewhat gruesome images of dead animals further into this video. I just played the first section for my kids, through 1:06.)

Part 2: Board Game — The Effects of Climate Change on the Quetzal (40 min.)

Overview of Game Rules

A video overview of gameplay is available at bit.ly/QuetzalConundrumVideo. Highly recommend you watch this!

The goal: This is a cooperative partner game. The goal is to work together to survive the changing climate.

Players: One person plays the quetzal (three pieces/individuals); the other plays the avocado (five pieces/individuals, numbered 1-5). If necessary, the avocado could be played by two people (one with two pieces, the other with three).

Game board: The game is played in three rounds: 2017, 2025, and 2050. The temperature for each life zone for each round is marked on the board. Life zone 4 is at the bottom of the "mountain," and life zone 1 is at the top. The "T" underneath the temperature indicates that there are toucans present for that life zone in that round.

Overview of instructions (see student game rule sheets for more detail):

1. Before the beginning of the game, students circle the current temperatures for each life zone using an Expo marker.
2. The avocado player chooses which zones to place their pieces in based on the temperatures of each zone. After this, the quetzal player places their pieces. (See student game rule sheets for **placement rules.**)
3. Students draw the current board set-up on their "Species Data Tracking Sheets."
4. Players play out the round. The avocado player rolls a six-sided die to determine what happens. If the player rolls 1-5, that tree "fruits" and any quetzals in that life zone can eat the fruit. The quetzal player may move each of their pieces a maximum of one life zone in order to find something to eat. For example, a quetzal in life zone 3 could move to life zone 2 if an avocado tree fruited there.
5. If you roll 6, look and see if any of the quetzal pieces is in a "toucan danger zone." If so,

one of the quetzal eggs is eaten by the toucan, meaning that one quetzal will not have any offspring. To represent this, one quetzal piece is removed for the rest of the game (including future rounds). The quetzal player can choose which piece to remove.

6. Roll up to four times per round. This does not count re-rolls. Re-roll rules are designed to take into account that an avocado tree can only fruit once per round, and that a dead avocado tree cannot fruit. (See game rule sheets for details on re-rolls.)
7. If a quetzal cannot find a fruiting avocado to eat by the end of the round, it is removed permanently.
8. After each round, students indicate the individuals that have survived on their species data tracking sheets.
9. Between rounds, players switch the temperature markings on the game board with the Expo marker. Turn all the game pieces that are still alive back to their starting side, and remove quetzal pieces from on top of avocado pieces. The climate changes, and the players may move their pieces accordingly. (See student character sheets for **placement rules**.)
10. Before the beginning of the round, students mark the new species distribution data on their data tracking sheets.
11. Remind students that between each round they are moving 25 years into the future. The game pieces do not represent the same individual that they did in the previous round. In the case of birds, they are the "great-great-great-…grandkids" of the individual in the first round, and in the case of trees, probably the "kids" or grandkids of the first individual.
12. Students play three rounds, marking species distribution before and after each round.
13. In pairs, students fill out reflection sheets.
14. Come together for a group discussion. See the discussion guide.

Notes on Placement of Pieces

Toucans can live only in life zones that have average temperatures of **68° F or above.** Wild avocadoes can live only in life zones that have average temperatures of **64-70° F**. Quetzals can live in any life zone that had an avocado tree in it in the **previous round**.

If students follow these guidelines correctly:

- For round one (2017): avocado trees can be in zones 2-4 and quetzals in zones 2-4. Zone 4 is a "toucan danger zone."
- For round two (2025): there should be avocado trees in only Zones 2 and 3 now. Quetzals can be in zones 2-4, as long as there was at least one avocado tree there in Round 1. Zones 3 and 4 are "toucan danger zones."
- For round three (2050): There should be avocado trees only in zone 2 now. Quetzals can be in zones 2-3, as long as there was at least one avocado tree there in Round 2. Zones 2-4 are "toucan danger zones."

Note the **space limits** in each zone for avocado trees — maximum of four trees in zone 4; three trees in zone 3; two trees in zone 2; and one tree in zone 1. These limits reflect the fact that there is less space as one moves up the mountain.

Rationale for Placement Guidelines

Placement Guideline	Rationale
Temperature range for trees	Temperature, and more broadly, climate, determine: how much water the tree has access to, and how quickly all the biochemical reactions in the cells can "run"
Trees can be placed only in a life zone where there has been a quetzal	Trees cannot walk; they depend on the quetzal for seed dispersal
Only four trees can be in Life Zone 4, three trees in Life Zone 2, etc.	As one moves up a mountain, there is less space available
Quetzals can be placed only in a life zone where there are trees	Quetzals need to eat! And in the wild, quetzals migrate in synchrony with the fruiting of the avocado trees
Toucan "danger zones" move up the mountain as temperature increases	This mirrors the trends that ornithologists are observing in Costa Rica

Predicted Game Outcomes

Avocado trees will have fewer spaces where they can grow, resulting in drastically shrinking populations, particularly in round 3. They will "want" to move to life zone 1, but they won't be able to, since the quetzal player won't have been able to place their pieces there in previous rounds. Eventually, there will not be enough food for all the quetzals to eat. Also, increasingly, the quetzal eggs will be eaten by the toucan, as toucans are present in more life zones.

Key understandings

1. The quetzal and the wild avocado are completely dependent on each other for survival: The quetzal depends on the wild avocado for food, and the wild avocado depends on the quetzal for seed dispersal.
2. As the temperatures increase due to climate change, avocado trees are not able to move up the mountain to "follow" their ideal temperatures, since quetzals do not drop their seeds there (since there are no avocado trees there to start with). In other words: Avocado trees die out ↘ quetzal population shrinks ↘ avocado less able to adapt to climate change, avocado trees die out ↘ … **a reinforcing loop that might end in extinction of these populations.** Avocado trees dying out is also part of another reinforcing loop: Temperatures increase ↘ avocado trees die out ↘ more CO_2 in atmosphere ↘ temperatures increase …
3. The toucan also "moves up the mountain" as the climate warms, further threatening the quetzal.

Part 3: Reflection and Class Discussion (25 min.)

Partners complete reflections. Then, gather together as a class. Go through partners' reflections.

Particular focus on solutions:

What could people do to help prevent the quetzal and wild avocado from going extinct? (Reforestation, particularly of farming lands.

This is a major dairy farming area. How could you convince famers to reforest grazing land? Also, human planting of the wild avocado at higher elevations? See "resources for follow-up discussions" for more ideas.)

Other questions to discuss as a group:

1. How could we describe the interactions between quetzal, avocado, and climate changes as a reinforcing loop? (See "key understandings.")
2. According to this simulation, how might climate change impact the toucan?

   (Population might increase as it had increased range and ability to eat the quetzal eggs.)
3. Do you think the quetzal could evolve to eat other foods, and thus avoid being affected as much by climate change? Why or why not? (The quetzal is so specifically evolved to the avocado, that it might be difficult, although we know that it can eat insects and possibly other fruits as well.)
4. What about this simulation accurately represented the process of climate change? What did not? (Students should notice in particular the overly simplified climate description of each life zone; avocadoes need high levels of precipitation to live, in addition to their temperature range. Also, we ignored factors such as availability of nesting trees — food is not the only limiting factor at play. And, of course, the thousands of quetzals and hundreds of wild avocados were represented by just a handful of game pieces.)

Resources for Background or Follow-up Discussions/Activities

Relevant non-fiction articles, available at multiple Lexile levels through www.newsela.com:

- "Fact or Fiction? The Sixth Mass Extinction Can Be Stopped" bit.ly/2sLmvg9
- "Understanding Tropical Deforestation" bit.ly/2rLPfnx
- "What is biodiversity?" http://bit.ly/2zuiP4M

Resources for teaching about Systems Dynamics and Systems Thinking:

http://www.clexchange.org/

http://bit.ly/HabitsofThinkers

http://bit.ly/LindaBoothSweeney

Background Information

The resplendent quetzal, endemic to only narrow swaths of Central America, is predicted to be one of the species most threatened by climate change. Adult quetzals are fruit-eaters, particularly eating various species of wild avocado. In Monteverde, Costa Rica, for example, quetzals migrate between five life zones (areas of habitation at different elevations), in synchrony with the fruiting of the avocado trees.

Quetzals have special adaptations to allow them to swallow the avocado, which (as you can see in the photo below) is often larger than their skull. They digest the avocado in their stomach over the course of around half an hour, then vomit up the pit. This is one of the only methods of seed dispersal for the wild avocado, which in the evolutionary past relied mostly on dispersal by (now extinct) megafauna.

As the climate changes, the timing of the avocado trees' fruiting has begun to become disrupted, and the zones that the avocado can live in are moving up in elevation. However, quetzals and other fruit-eating birds are not necessarily moving the seeds of the avocado to these new zones:There are no avocado trees there already, so there is no incentive for them to move there. To add to the quetzal's woes, the toucan, which used to live primarily in lower elevation zones, has been moving up into the quetzal's territory as temperatures increase — and sometimes eating the quetzal's eggs. Also, much of the quetzal's habitat has been deforested for farmland. Thus, the narrowing of the range of the avocado will lead to the narrowing of the range and the possible extinction of the resplendent quetzal.

In Monteverde, much of the land is taken up with dairy farms — including land that used to be home to the quetzal. Until recently, the Monteverde Cheese Factory was owned by a board of local farmers and community members. Dairy farming remains the sustenance for many of the families in Monteverde. Unfortunately, the increasingly extreme weather events associated with climate change, particularly droughts and floods, have made dairy farming more difficult to sustain in the community.

These two needs — for farmland and for habitat for the quetzal — would appear to be in conflict. How can students reconcile these two perspectives? *This board game simulation is designed to have students engage with this conundrum and to think about the difficult and complex work of environmental activism.*

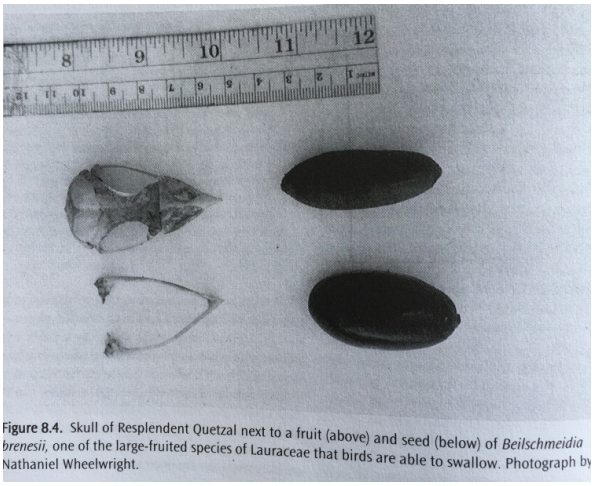

Figure 8.4. Skull of Resplendent Quetzal next to a fruit (above) and seed (below) of *Beilschmeidia brenesii*, one of the large-fruited species of Lauraceae that birds are able to swallow. Photograph by Nathaniel Wheelwright.

Nadkarni and Wheelright, 2001

The skull of the resplendent quetzal next to the seeds of the wild avocado.

Overview
Acknowledgements

Many thanks to the following educators, scientists, farmers, and students for their help in designing, play-testing, and revising this game:

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- Bethany Elmore, Monteverde Institute
- Sarah Stuckey, Stuckey Farm, Monteverde
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- Max Hoffman
- Matt Lawlor
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- Ms. Lisa's 5th- and 6th-grade students at Neighborhood School, Jamaica Plain, Mass., 2016–2017 school year

Game Rules

Resplendent Quetzal

Game 1

Goal: Work with your partner(s) to be as **resilient** as possible to the effects of climate change. In other words: Survive! You depend on the avocado as your food source.

For each of the three rounds:

1. Once the avocado trees have all been placed, **set up your pieces** in any zone in which there are trees. Mark the placement on the species-tracking sheet.

2. **Roll the die four times**, alternating with your partner. (If you roll the same number [1-5] again, or roll the number of an avocado piece that has already been removed, you may re-roll.)

   Roll a 1, 2, 3, 4, or 5? The avocado tree with the matching number gets flipped over to "fruiting."

   Roll a 6? If one or more quetzal is in a toucan danger zone, one of them must be removed from the game, since its eggs have been eaten!

3. After the four rolls, quetzals can now **eat from the fruiting trees**. You may move each piece one life zone to a fruiting tree. Flip your piece over to "full" and place it on top of the avocado piece.

4. If there are not enough fruiting trees available, any remaining hungry quetzals starve. Remove these pieces for the rest of the game.

5. Mark the final piece placement on your species-tracking sheet.

Game Rules

Wild Avocado

Game 1

Goal: Work with your partner(s) to be as **resilient** as possible to the effects of climate change. In other words: Survive! You depend on the quetzal to disperse your seeds.

For each of the three rounds:

1. **Set up pieces and mark the placement** on the species-tracking sheet. Pieces may only be placed in life zones where:
   a. the average temperature is 64-70° F.
   b. there is enough space left in the zone (not more than one tree in zone 1, two trees in zone 2, etc.).
   c. For rounds two and three: there has been a quetzal there the previous round to drop your seeds

2. **Roll the die four times**, alternating with your partner. (If you roll the same number [1-5] again, or roll the number of an avocado piece that has already been removed, you may re-roll.)

   Roll a 1, 2, 3, 4, or 5? Flip the avocado tree with the matching number over to "fruiting."

   Roll a 6? If one or more quetzal is in a toucan danger zone, one of them must be removed from the game, since its eggs have been eaten!

3. Quetzals can now eat from the fruiting trees.

4. Mark the final piece placement on your species-tracking sheet.

Avocado Tree 1 not fruiting

Avocado Tree 2 not fruiting

Avocado Tree 3 not fruiting

Avocado Tree 4 not fruiting

Avocado Tree 5 not fruiting

Hungry quetzal

Hungry quetzal

Hungry quetzal

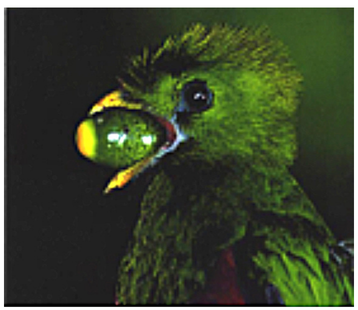
Print this page and the next page double-sided on cardstock to create the game pieces.


Avocado Tree 4 fruiting!

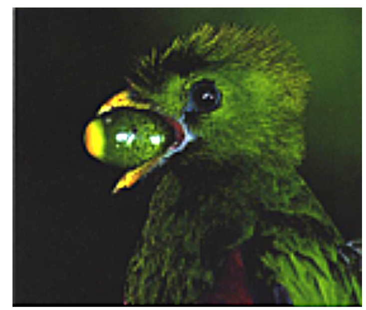

Avocado Tree 3 fruiting!


Avocado Tree 2 fruiting!


Avocado Tree 1 fruiting!


Full quetzal


Full quetzal


Full quetzal

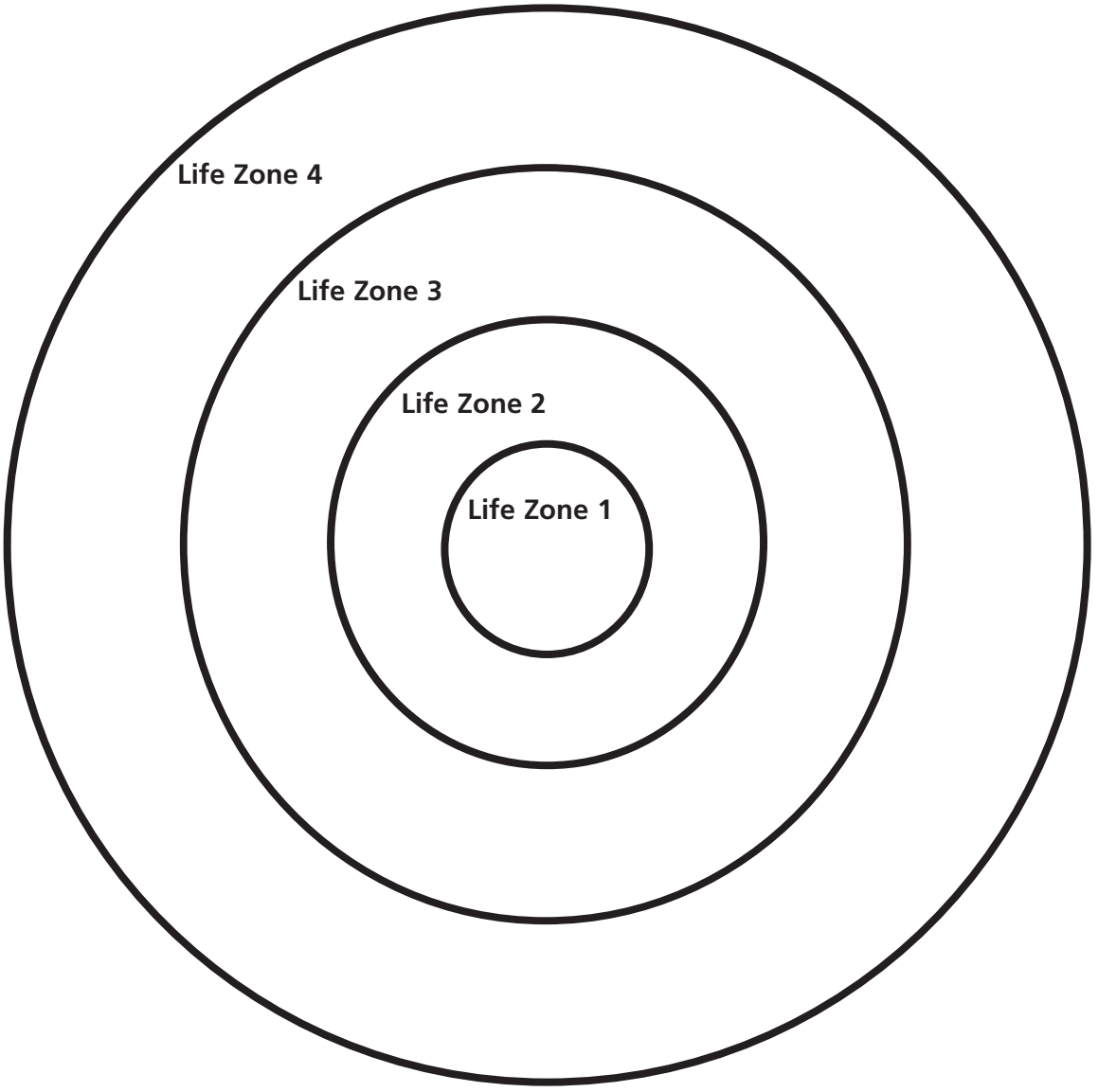

Avocado Tree 5 fruiting!

Names: _____

Species Data Tracking Sheets

Directions: Before and after each round, mark down the locations of each individual that is still alive. Q=quetzal; A=avocado tree

Before 2017



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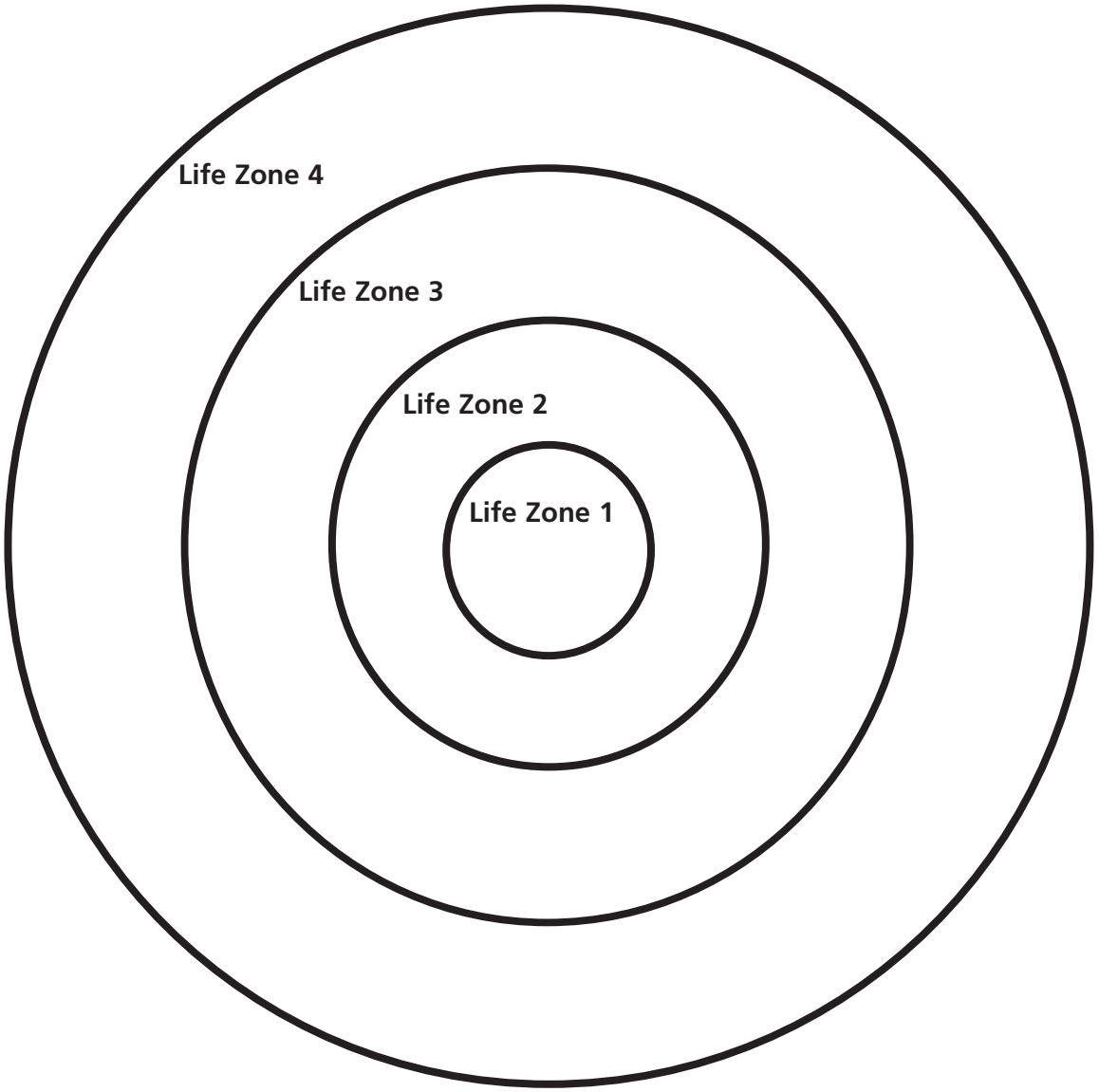
Species Data Tracking Sheets

Directions: Before and after each round, mark down the locations of each individual that is still alive. Q=quetzal; A=avocado tree

After 2017



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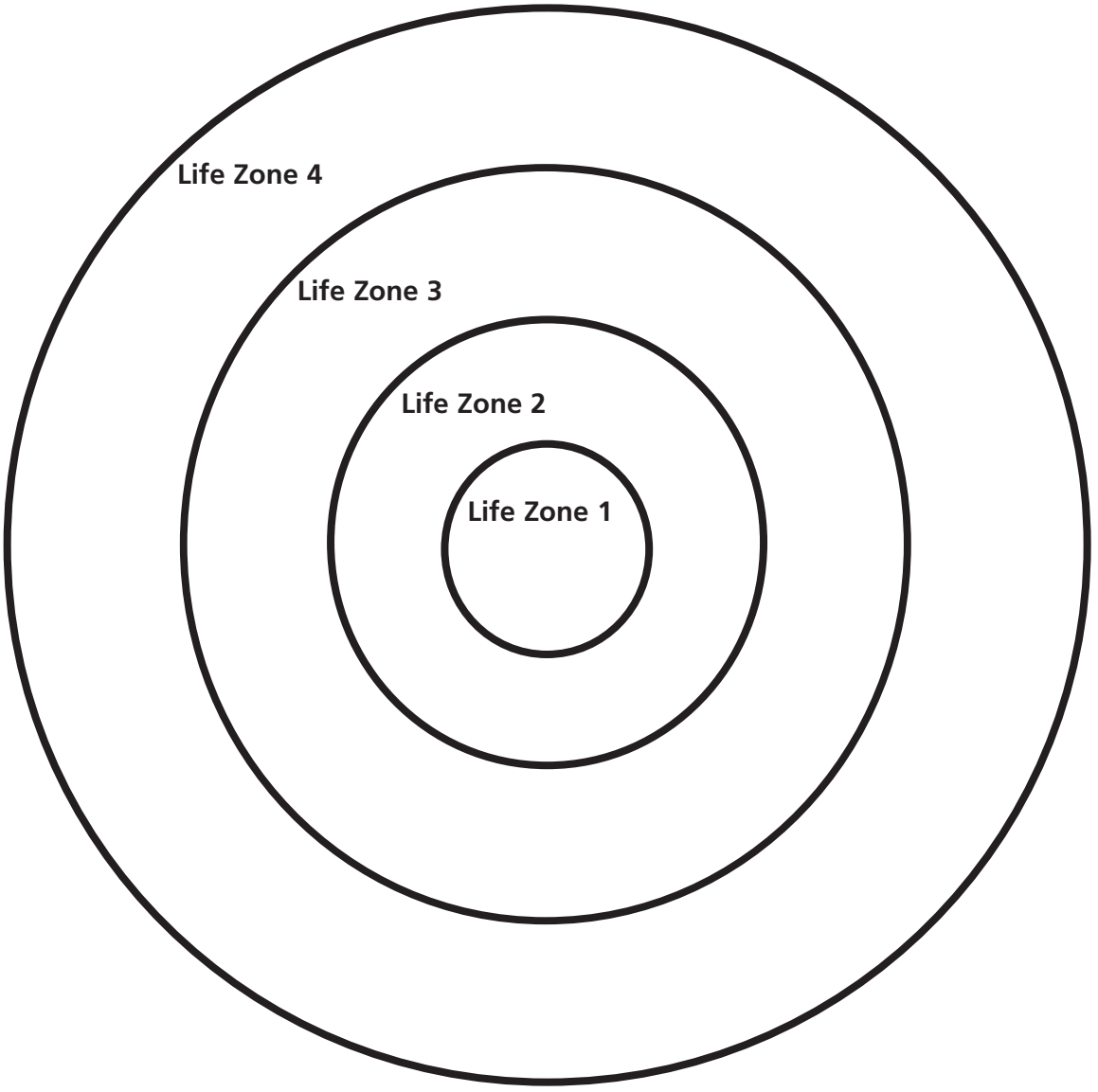
Species Data Tracking Sheets

Directions: Before and after each round, mark down the locations of each individual that is still alive. Q=quetzal; A=avocado tree

Before 2025



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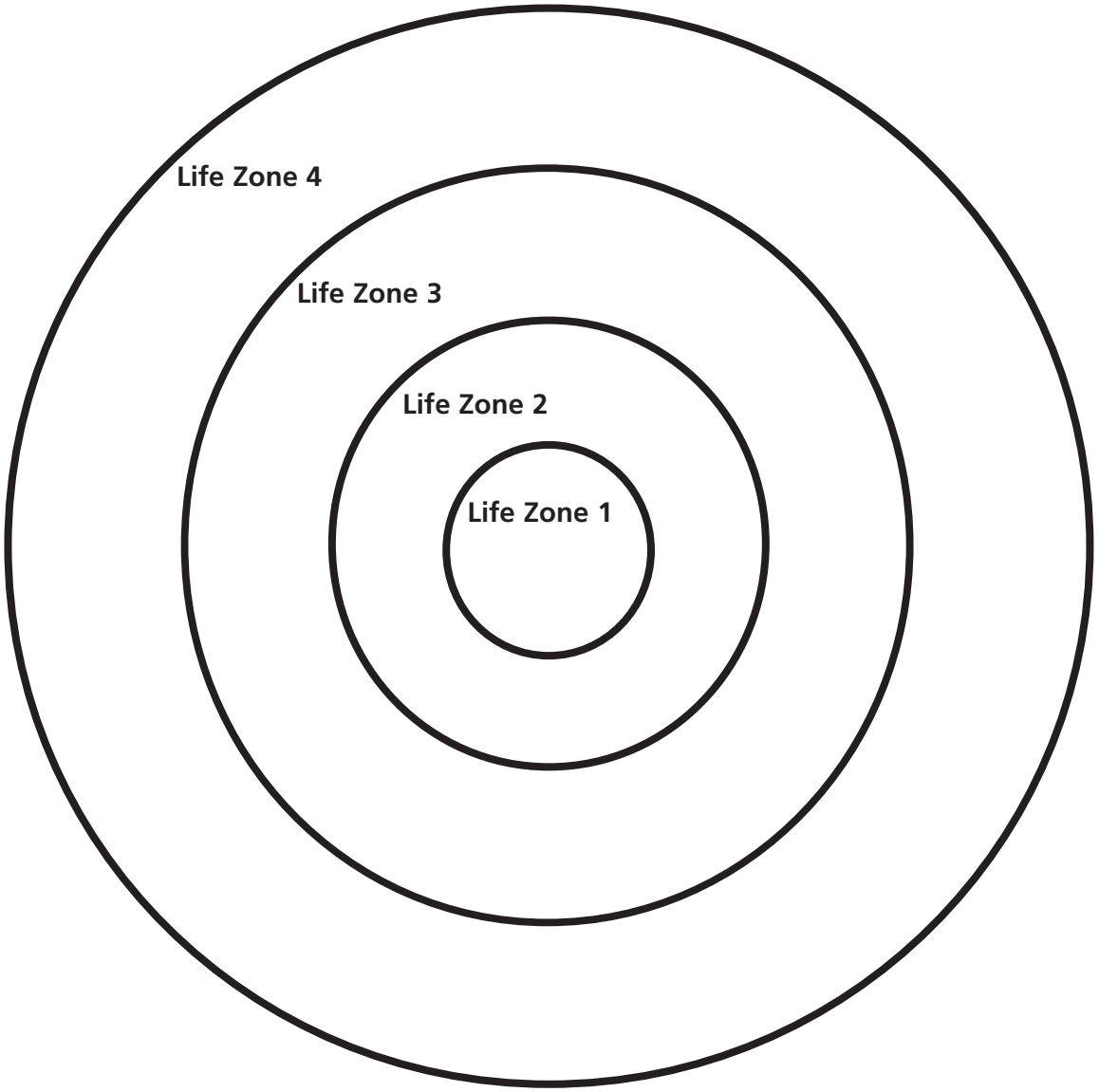
Species Data Tracking Sheets

Directions: Before and after each round, mark down the locations of each individual that is still alive. Q=quetzal; A=avocado tree

After 2025



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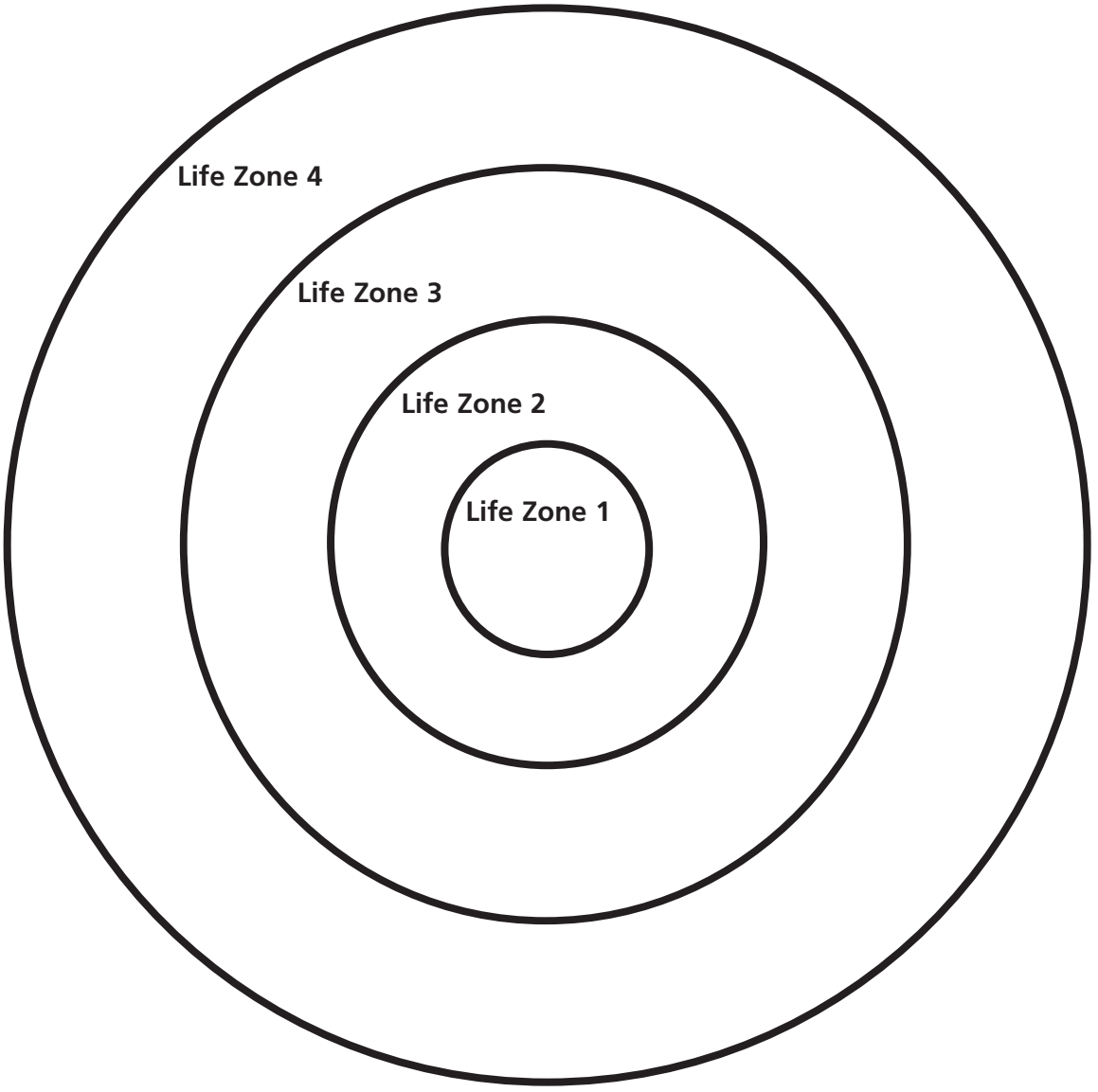
Species Data Tracking Sheets

Directions: Before and after each round, mark down the locations of each individual that is still alive. Q=quetzal; A=avocado tree

Before 2050

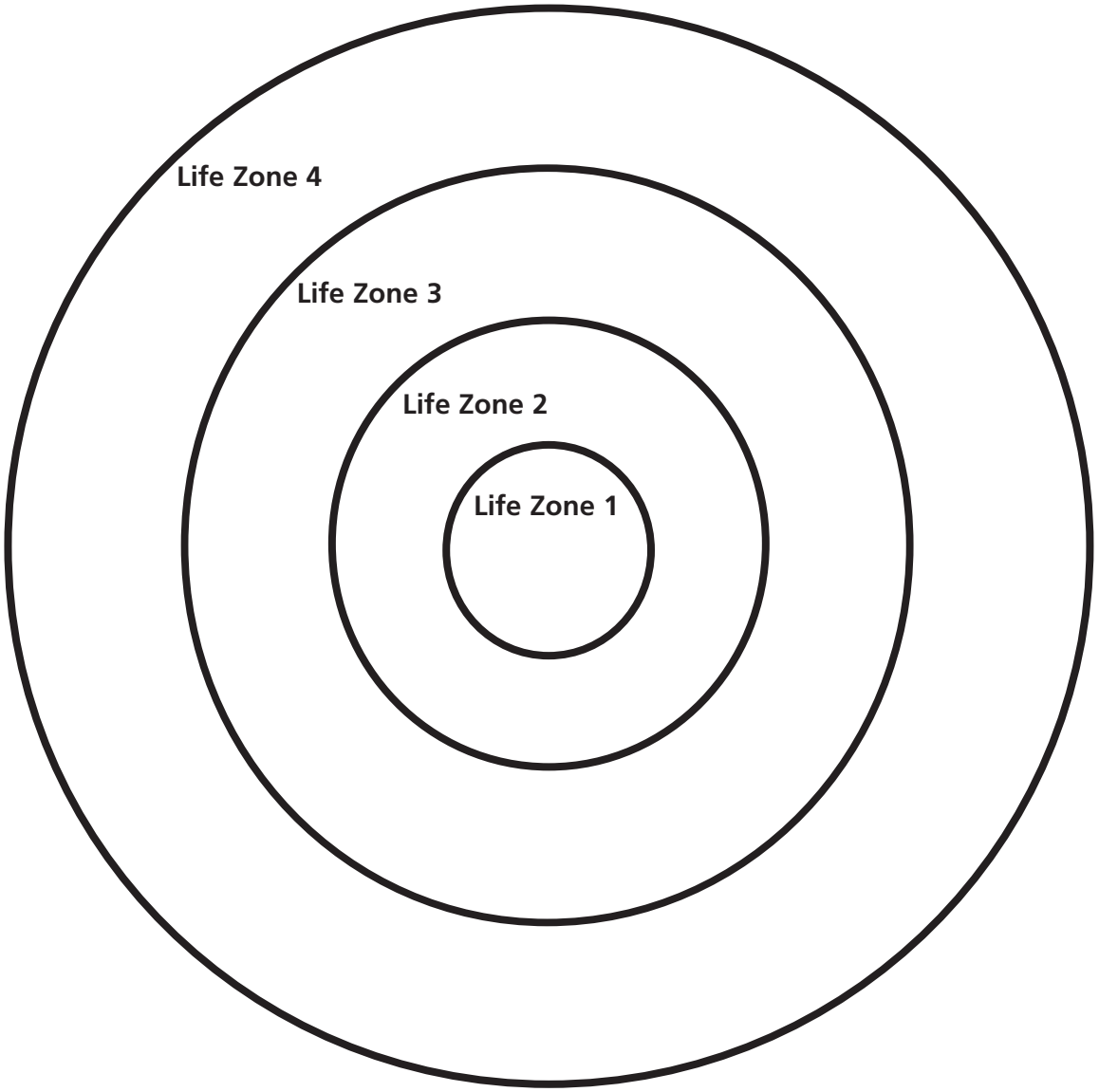


Names: _____

Species Data Tracking Sheets

Directions: Before and after each round, mark down the locations of each individual that is still alive. Q=quetzal; A=avocado tree

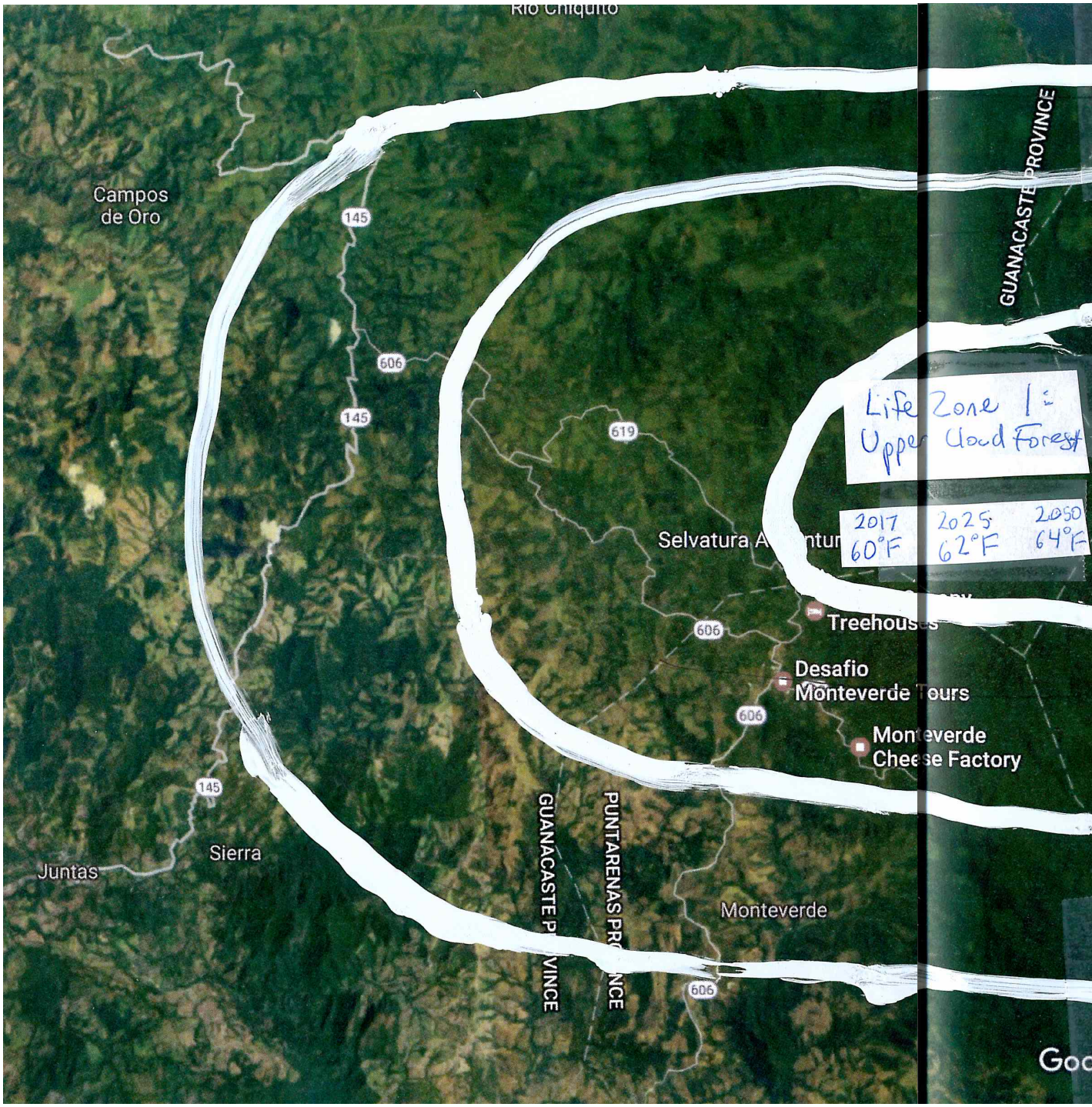
After 2050



The Quetzal Conundrum

The Children's Eternal Rain Forest

Monteverde, Costa Rica




Life Zone 2:
Lower Cloud Forest
2017 2025 2050
64°F 66°F 69°F
T
Bosque Eterno
de los Niños
Life Zone 3:
Rain Shadow Forest
2017 2025 2050
67°F 69°F 71°F
T
T
Life Zone 4:
Moist Forest
2017 2025 2050
70°F 72°F 74°F
T
T
T
Pocosol
La Tigra
702
702

Names: _____

The Quetzal Conundrum: Reflection

Directions: Work with your partner(s) to answer the following questions.

1. According to this simulation, how might climate change impact the **avocado tree**? Why?

2. According to this simulation, how might climate change impact the **quetzal**? Why?

3. In rounds two and three, why **wasn't** the avocado tree able to move into life zone 1, even when that zone had the best average temperature?

4. In your opinion, what could humans do to help prevent the quetzal and wild avocado from going extinct in the Eternal Children's Rainforest?