The author Wendell Berry once said, “The Earth is what we all have in common.” As societies become more globalized through communication and trade, we all become connected to distant places in surprising ways. This high school life science unit introduces students to the intersection of science, economics, geography, and culture through the current practices of palm oil cultivation in the tropics. For this article, we travelled to Sabah Province, Malaysia, to visit palm oil plantations, conduct interviews, and collect resources to help students better understand how this industry affects biodiversity in tropical ecosystems and how students are connected to palm oil production as consumers through global supply chains.

Students began the unit by analyzing data to understand how primary forest destruction for palm oil cultivation threatens biodiversity, and by exploring the variety of consumer products in their lives containing palm oil. Next, students conducted an investigation in order to learn how scientists measure biodiversity, and then used adapted primary literature to analyze real data about ant biodiversity taken from a real field study. Students then applied the knowledge that they gained about biodiversity and ecosystems to a variety of other contexts. Students ended the unit by discussing potential actions that could be taken to address the issues they explored.
The biodiversity crisis in the tropics

Biodiversity refers to the variety of life found in Earth's biosphere. Due to human population growth and increasing consumer demand, the world's biodiversity is being lost at an accelerating rate. Higher levels of biodiversity are linked to increased ecosystem health, such as better soil formation, nutrient storage, pollution breakdown, and ability to recover from various natural disasters. Loss of biodiversity within an ecosystem has roughly the same capacity to negatively affect an ecosystem as the impact of major environmental stressors such as climate change (Cardinale et al. 2012).

Tropical forests contain the highest levels of biodiversity in the world (Gibson et al. 2011), and therefore deforestation should be understood and taken seriously. A current major threat to tropical forests is the clearing of primary forest land for the production of palm oil, cultivated from oil palm trees, reducing what was a complex ecosystem to a single monoculture (Figure 1). The majority of the world's palm oil production is currently localized in Indonesia and Malaysia (Paddison et al. 2014).

The American consumer is inextricably linked to the palm oil industry. Palm oil is found in consumer products including peanut butter, ice cream, soap, baked goods, lipstick, and margarine. While sometimes it is relatively easy to identify palm oil as an ingredient on product packaging, it often is listed under unrecognizable names such as cetyl alcohol, sodium lauryl sulfate, or stearic acid. This lack of transparency makes it difficult for the average consumer to know whether or not palm oil is in a given product. Figure 2 shows an image of the fruit from the oil palm tree from which palm oil is derived.

Worldwide demand for palm oil continues to increase. The palm oil industry is now expanding to locations with rich biodiversity such as South America, Central America and parts of Africa (Vijay et al. 2016). Websites such as Love My Palm Oil (see Online Connections), have been used to sway the opinions of Malaysian citizens by selecting only positive stories about palm oil—specifically stories that emphasize the income that this cash crop can bring to the economy and that ignore the drawbacks. Some of the world's biggest brands have committed
to better practices for palm oil production in their global supply chains, but not all have met their goals.

Palm oil production has led to the destruction of primary forests in the tropics; however, tropical forests generally have greater long-term economic value when preserved in their natural states. The economic value of leaving the forests untouched includes local flood prevention, a clean water supply, tourism, increased food supply, increased biodiversity, carbon sequestration, timber and forest products (Van Beukering, Cesar, and Janssen 2003).

Some companies attempt to minimize the harm done to both the environment and native people, and can obtain Roundtable on Sustainable Palm Oil (RSPO) certifications that prove they have taken steps to minimize this impact. While this is a positive step, recent research has pointed out major loopholes in this certification—for example if someone else deforested the land previously, the RSPO certification process does not hold companies that currently own the land accountable for this impact (Gatti et al. 2019). For further information, the Rainforest Action Network corporate scorecard is available in the Online Connections section and provides information on how specific brands are doing.

Using adapted primary literature
Working with published research articles is one way to give students an insight into how real science is done and is a way to connect science learning to the relevant questions and problems that these articles address. A 2005 study found that high school biology students who read adapted primary literature were able to summarize science content equally well as students working with secondary literature; the primary literature student group, however, demonstrated better inquiry skills (Baram-Tsabari and Yarden 2005). The same study found, however, that students working with secondary literature had more positive attitudes toward their reading tasks, though attitudes about reading primary literature improved steadily from 9th to 12th grade.

Primary literature needs to be scaffolded based on students’ prior knowledge and reading level. Using primary literature does not have to be an all-or-nothing strategy. Editing, selecting excerpts, changing the reading level of texts, or using close reading strategies could all be ways to make primary scientific literature accessible to high school students. While challenging to implement, adapted primary literature strategies best mirror how scientists read and write and are reflected in several of the NGSS science and engineering practices.

For our unit we relied heavily on an article by Fayle et al. (2010) from the journal Applied and Basic Ecology as a way to teach the NGSS disciplinary core idea LS2.C: Ecosystem Dynamics, Functioning, and Resilience. To make this article accessible to students, we first generated interest in the problem, introduced key concepts, and had students measure biodiversity using procedures similar to the authors in the study before ever showing students the actual article. This strategy worked quite well. When we finally introduced the article, students were primed to understand the research methods at a deeper level, care about the issues being explored, and were well prepared to ask critical questions of the author’s conclusions.

Description of the unit
The focus of the unit is to understand how global changes affect the interaction of species within ecosystems. We explored the impact of the palm oil industry on the biodiversity of ant species in Malaysia, and then applied that learning to new contexts. The unit is divided into three parts. Several formative assessments are provided as supplemental online resources to help interested teachers to facilitate these lessons (see Online Connections).

Part 1. Understanding the issue (2 class periods)
To start the unit, students brought in wrappers of various food packaging items that they recently consumed. As students arrived to class, they deposited their items into a large collection bin. In groups of two, we instructed students to sort through some of the bin items while answering the following questions:

- What are some common ingredients that you see in all of the food packaging items?
- Which of these ingredients are you most familiar with?
- Identify at least two ingredients that you are unfamiliar with.
- Choose one ingredient and predict where you believe it may have come from.

Next, the teacher asked the class, “Is anyone familiar with palm oil?” In our class, no one raised their hand. The class began an interactive WebQuest using an online article from The Guardian about the palm oil industry (see Online Connections). The interactive site allowed students to compare the value of
a tropical forest when it is conserved vs. its value when it is cut down. A worksheet to support students as they obtain and evaluate information from the WebQuest is posted online as a supplemental resource.

The students then revisited their food packaging labels, but this time to sort the items into two piles; one pile included items that contain palm oil and the second included items that did not explicitly list palm oil as an ingredient. Once the students had sorted their items properly, they were given a list of other names for palm oil that companies may use (see Online Connections). Depending on time available, the shorter list provided in Figure 3 could be provided to students instead.

The students examined the collection of products that ostensibly do not contain palm oil to look again for any of the alternative names. At the end of the activity, the items that contain palm oil grew considerably. Students were very interested to know why there were so many names for this product. Part I ended with three questions that we discussed as a whole class:

1. What is biodiversity? How does palm oil production affect biodiversity?
2. Why might companies want to conceal palm oil as an ingredient from consumers?
3. How can we balance our own interests and needs with the health of the environment?

### FIGURE 3

**Alternative names for palm oil on consumer labels.**

- cetyl alcohol
- cetyl palmitate
- elaeis guineensis
- ethylhexyl stearate
- ethyl palmitate
- fatty acids
- octyl palmitate
- octyl stearate
- palm kernel oil
- palmitate
- sodium laurel sulfate
- sodium palmitate
- sodium stearate
- stearic acid
- stearyl acetate
- stearyl tartarate
- vegetable emulsifier
- vegetable oil
- zinc myristate
- zinc stearate

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### Part 2. Using adapted primary literature (2 class periods)

We introduced the study by Fayle et al. (2010) to share the main research question that the scientists were trying to investigate: understanding the effects of the palm oil industry on indicator species (in this case, ants) in Sabah, Malaysia. We explained that before examining the article, students would first conduct an experiment using the same methods that the scientists used in order to better understand their findings.

To begin the experiment, the teacher asked the following questions:

1. How might ecologists determine the population of a species such as an orangutan in a given area? (Students responded that they may use drones or set up cameras to track animals).

2. Can we use the same techniques when trying to measure the population of smaller species, like ants? (Students were stumped for a while. One student replied that they could count them by using food as bait).
In order to provide students with an opportunity to understand how to measure ant biodiversity, the teacher set up a large paper area on the floor divided into square sections. Any size grid can be used for this activity, but spreading out a large sheet of paper on the floor made it feel like the class was taking a field trip to a remote forest location. Ecologists use this “transect” method to sample a small number of organisms to make inferences about larger populations. Food sprinkles of different colors were dropped unevenly by the teacher into the transect area as simulated ants, each color representing a different species. Students were assigned to different squares in the grid to measure the total number of each color of sprinkle (ant) in their area.

Students recorded the frequency of colors in their own grid, shared data in a central location, and then calculated class averages over the entire transect area. We asked students to brainstorm a list of possible sources of error with measuring ants in this way. A worksheet to guide this activity can be found as a supplemental online resource (see Online Connections). Students were excited to replicate an actual scientific experiment. One student called out, “This is so cool, I feel like we are doing real science!” (See Figure 4).

In the next class period, students analyzed real data from the Fayle et al. (2010) article, whose authors used methods to sample biodiversity similar to what students did the previous day. Students were provided sampling data from the article showing ant species richness from three different sub-habitats in both the untouched primary forests and oil palm plantations. These three sub-habitats included (1) the leaf litter on the forest floor, (2) the canopy, and (3) an epiphytic bird nest’s fern endemic to the trees (Asplenium nidus). Another supplemental online resource was posted to help scaffold students’ analysis of the article’s data (see Online Connections). Students found that there was a more serious loss of species richness on the forest floor of palm oil plantations as a result of increased temperature due to more direct sunlight exposure, while there were less-extreme changes for ant species inhabiting the other two subhabitats.

In closing, each student was given a paper copy of the full scientific paper. First, the teacher read the abstract to students while they followed along. Students were then given an opportunity to independently read just the abstract. As they read, students underlined phrases and circled words they were unfamiliar with. Next, as a whole group, students were called on to read the abstract a few sentences at a time. After every few sentences, students stopped and discussed the meaning of those sentences with a partner. Students felt challenged, yet proud, that they could now read and understand primary source material, many for the very first time.

**Part 3. Extending learning and revisiting the central focus (1 class period)**

In the final class period, as students walked into class, they began a “turn and talk” to answer the following question: *What is biodi-

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**FIGURE 4**

Students measuring biodiversity using the transect method.

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**FIGURE 5**

Guide for discussing culture in science class.

1. Share photos, videos, and stories that show scientific phenomena contextualized in a specific place and time that connect science and culture. Authentic materials (i.e., textiles, currency, artwork) may also be helpful depending on the topic.
2. Share positive aspects of cultures as a way to generate interest and to demonstrate relevance.
3. Allow students to explore how a local culture may view a phenomenon being studied in similar or different ways to someone outside that culture (emic vs. etic perspectives). Highlighting different ways of knowing is a good way to teach certain aspects of the nature of science.
4. Have students spend time considering the points of view of multiple stakeholders connected to any phenomenon or problem.
5. Don’t design engineering lessons where the goal is to impose a solution on another culture. Instead, structure problems so that students must develop solutions through understanding how different stakeholders will be affected and to work in conjunction with local agencies or industries (not to dictate solutions to them).
6. Highlight power differences both within and between cultures while considering the different ways cultures may interact (i.e., through commerce, immigration, or politics), and potential tradeoffs between cultural considerations, costs, environmental impacts, etc. when studying any complex issue.
It may be a new concept that discussions about culture would take place in a science classroom, yet doing so is one way to contextualize science and give students a powerful reason for why they should care about what they’re learning.

versity and why should you care about the preservation of biodiversity? Students were given a final worksheet that extended the science concepts learned in the unit beyond the context of Malaysia using other mini-case studies (see Online Connections), including:

1. The mussel’s ability to remove contaminants from water through filtration.
2. The mangrove’s connection to flood prevention for coastal communities.
3. Ecosystem disruptions connected to Antarctic and Arctic icecap melting.

In the final 15 minutes of class, students discussed what they might do on their own to protect biodiversity, related to what they learned about palm oil cultivation. Some possible suggestions included:

1. Read ingredient labels on all products, or use apps like PalmSmart to scan product barcodes to learn more about them prior to purchase.
2. Look for “palm-oil free” certification stamps on the front of products.
3. Write letters to product manufacturers about the need to find alternatives to palm oil.
4. Write letters to elected representatives about your concerns related to palm oil production.
5. Eat home cooked meals with non-processed foods, and use other cooking oils (such as olive oil or sunflower oil)
6. Educate others.

Bringing culture into science class

It may be a new concept that discussions about culture would take place in a science classroom, yet doing so is one way to contextualize science and give students a powerful reason for why they should care about what they’re learning. At various times in this unit, students considered the impact of the palm oil industry on the local culture and environment in Sabah, Malaysia, and also considered how different cultures are connected through global supply chains. We recognize that some teachers may feel hesitant the first time they facilitate discussions involving culture. Figure 5 therefore provides some useful tips for responsibly discussing culture.

Conclusion

We designed this unit to show students that science is relevant to their daily lives and that they are connected to issues affecting distant places. The topic of palm oil production captured their interest, and students eagerly continued to pursue this issue following the completion of the unit. By combining the use of adapted primary literature with a meaningful, project-based learning experience, students did not experience negative attitudes toward reading primary sources that were previously reported by Baram-Tsabari and Yarden (2005). It may be the case that combining adapted primary literature with project-based learning could be an especially effective strategy and a topic worthy of future study.

ONLINE CONNECTIONS

Analysis of data practice: https://bit.ly/3ilhA1g
Why is biodiversity important? https://bit.ly/3nXiBMC
Sprinkle sampling activity: https://bit.ly/31Ib1Az
Rainforest Action Network Corporate Scorecard: https://www.ran.org/sf02scorecard/
Interactive Guardian Story on Palm Oil: https://www.theguardian.com/sustainable-business/ng-interactive/2014/nov/10/palm-oil-rainforest-cupboard-interactive
List of Names of Palm Oil found in Common Products: https://toxinfreetribe.com/other-palm-oil-names/

References


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