Overharvesting

Future of Agriculture Curriculum for Teaching Sustainability

Name: _____   Hour_____ Date: _____

Date Packet is due:_____   Why late? _____   Score: _____
<small>Day of Week   Date</small>   <small>If your project was late, describe why</small>

Overview: in this unit, you will be learning about how overharvesting can lead to the extinction of living organisms.

Main Questions

- What is overharvesting and how does it occur?
- What are examples of species that are threatened by overharvesting?
- How can the overharvesting of a keystone species cause a cascade effect?
- How do scientists know if a species' population is dwindling, and how do they determine what the appropriate population is for a species?
- How can the idea of Tragedy of the Commons explain why people will sometimes wipe out a species even when it is clearly in decline?

Weekly Schedule

Monday:
- Introduction to Extinction – Data Dive

Tuesday:
- Nutshell Video & Notes
- Class discussion & revisions of explanations

Wednesday:
- The Fishing Game

Thursday:
- Review & Assessment

Friday:
- Weekly Reflection
- Career Connections

National Science Foundation WHERE DISCOVERIES BEGIN

KBS LTER Kellogg Biological Station Long-term Ecological Research

MICHIGAN STATE UNIVERSITY ®

Day 1: Data Dive – Overharvesting Case Studies

Introduction: In this activity, you will be considering ongoing case studies of overharvesting throughout the world. You will then consider data about current trends in regards to overharvesting to help you to develop ideas about long term trends on this topic.

Directions: As a group, use a computer, laptop, or personal device (if ok'd by your instructor) to look up information on your assigned cases using an internet search engine. Be prepared to summarize your group's examples for the rest of the class. You will also need to take time as a group to address the questions below prior to presenting. After each group has had a chance to present their cases, you will take time as a class to try to summarize any similarities or patterns that you might have observed that are common to most or all of the examples provided. *Note: internet searches on some of these topics may result in graphic images.*

Cases:
1. Chinese Pangolin
2. Beluga Sturgeon
3. Lydenburg Cycad
4. *Paphiopedilum urbanianum*
5. Ploughshare Tortoise
6. Bali Starling
7. Chinese Giant Salamander
8. African Elephant
9. Tiger (six remaining subspecies)
10. Burmese Python*
11. Black Rhinoceros
12. Giant Armadillo
13. Oceanic Whitetip
14. Cowan's Mantella
15. Elegance Coral
16. *Student Choice – if a student group has a species they'd like to investigate that is not listed above, they can do so if they receive instructor approval*
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> ### How to tell if a website is credible: BAR
>
> **Bias**: who is the author of this website? Why did they write this? Was it purely to inform, or are they trying to persuade the reader for their own personal gain?
>
> **Accuracy**: are their claims supported by valid data and/or logical arguments? Is the original primary source of this information cited? Are the authors sufficiently experienced and qualified to have reliable opinions on this topic? Is this website peer-reviewed, or can they post anything that they want regardless of its truthfulness?
>
> **Relevance**: is this information valuable for my needs? Does the level of detail in this site hurt my ability to get this work done in a timely fashion? What do other sources say? Does this agree with sites that are credible?
>
> *Generally, government [.gov] and university [.edu] websites are more credible than private [.com] websites. Wikipedia and other open-source sites are less reliable because they can be changed but may provide potentially-credible sources in the citations.*

Questions: Briefly summarize your case study species.
1. Describe the species – what are its key characteristics and unique attributes?
2. Why are its numbers declining?
3. What is the key factor that is causing it to be harvested so rapidly and extensively?
4. Is this problem being effectively addressed? Why or why not?
5. What is the most likely outcome for this species at the moment?
   Complete #6 after presentations have concluded
6. What commonalities did you notice across the different case study presentations?
7. What kinds of actions might most effectively protect species threatened by overharvesting?

Key overharvesting legal protections: The list below provides a brief description of each piece of legislation. Use an internet search engine to learn more about these laws and their protections.

- In the United States, the Endangered Species Act (ESA) is the key form of legal protection for species at risk of extinction due to overharvesting.
  - o Local and State regulations are also important for preventing overharvesting, especially of game species.
- Internationally, the Convention on International Trade in Endangered Species (CITES) of Wild Fauna and Flora (or *The Washington Convention*) is the most important legal protection for preventing the overharvesting of species.

Questions:
1. Briefly summarize how the legal protections listed above function to protect overharvested species from going extinct. (You may want to re-visit earlier units to get a brief refresher on the ESA; you'll need to use internet sources to learn more about CITES).
2. Are these legal protections sufficient to prevent widespread extinctions from overharvesting? Why or why not?
3. Are extinctions by overharvesting a thing of the past, or should more be done to address this problem?

Note: the Burmese python is both overharvested and an invasive species. In short, the species is overexploited for food and for its skin. They can also be illegally trapped and sold as pets; this has resulted in some pet owners releasing it into the wild after realizing how large it can grow. Because of a similar climate in Florida, this has resulted in the unique and ironic phenomenon of an overharvested species also becoming an invasive species – its native populations are too low, but its invasive populations are too high.

Day 2: Notes & Discussion

Introduction & Directions: In this activity, you will begin by watching a short video about **overharvesting**. This will help to clarify some of the questions you may have had yesterday. After the video, you will look at a short slideshow presentation that will provide you with specific information about this topic. Your instructor may decide to deliver the presentation as a classroom lecture or they may allow you to read the notes individually or in small groups (depending on your previous experience and capabilities with this content). You will work in small teams to answer the questions listed below. You should take notes in a notebook, on a dry erase board, or on scratch paper so that you are prepared to deliver your responses during the class discussion that will follow. *Note: your instructor may assign your group to answer specific questions if time is limited.*

URL Links

YouTube Video: https://www.youtube.com/watch?v=WNdR808jMSA

Slideshow Presentation: https://www.factsnsf.org/uploads/1/4/0/9/14095127/2018-6-3_facts_overharvesting.pdf (or visit factsnsf.org and use the menu bar).

Discussion Questions:
1. What is overharvesting? Does it only involve hunting and fishing?
2. Is overharvesting still occurring or was it primarily a past concern?
3. What are examples of species threatened by overharvesting?
4. How does overharvesting become more problematic if the species in question is also a keystone species?
5. What is the "cascade effect"? How does this relate to the overharvesting of keystone species?
6. How can government regulation prevent overharvesting?
7. How can scientists estimate the population of a species to determine if it is at risk of overharvesting?
8. Use the Mark-Recapture Method formula for determining the population of a species based on provided data.
9. What are "Boom and Bust Cycles"? How can this complicate the task of determining a species' population?
10. How does a species' survivorship type (Type 1, 2, or 3) affect its population management?
11. How does the carrying capacity of a species relate to population management? Are there exceptions to this?
12. What is the "Tragedy of the Commons"? How does it relate to the overharvesting of species?
13. Why does the Tragedy of the Commons occur? What are possible solutions for fixing this?

Be sure to revisit your explanations from the previous day's activity and add details or corrections as needed.

Day 3: The Fishing Game

Overview: In this activity, you will be playing a game that serves as a model for how Tragedy of the Commons occurs. Before starting, show the following video: https://www.youtube.com/watch?v=CxC161GvMPc

Materials: game pieces (such as poker chips, pieces of paper, paperclips, pennies, etc.).

Directions: You should play the game in groups of three or four. Each person in the group will be fishing for large fish in the same ocean. Put 20 "fish" in the middle of the table (use whatever your instructor has provided as game pieces as your fish). This is the *carrying capacity* for large fish in your ocean.

In each round, each person can fish for a certain number of large fish. You can fish in the following ways:

1. Harpoon fishing: take one fish.
2. Long-line fishing: take two fish.
3. Free-for-all long-line fishing: take three fish.

After each round when each player has taken their fish, the group needs to let their fish population "reproduce" to replenish the population with new baby fish. To do so, take the number of fish you have at the end of the round and divide by 4 to determine how many to add.

For example, if you have 12 fish left at the end of the round, you would add 3 fish ($12 \div 4 = 3$). If you do not get a whole number, round down to the nearest whole number. For example, if you had 14 fish left at the end of the round, you would still only add 3 fish ($14 \div 4 = 3.5 = 3$). Each game ends after 10 rounds, or when the fish population is completely depleted, whichever comes first.

You have two goals. The first is to individually collect as many fish as possible over the course of each game. The second is to have as many fish as possible remaining at the end of each game. **If your fish population reaches zero before the end of the game, you all lose the game.** Use scratch paper or a dry erase board to keep track of your fish population after each round and at the end of the game.

You will be playing four versions of this game:

1. Game 1: Everyone chooses a fishing method (harpoon, long-line, or free-for-all) at the start and cannot change.
2. Game 2: Everyone chooses a fishing method (harpoon, long-line, or free-for-all) at the start and but they can change their method after each round.
3. Game 3: Government Regulation – everyone is limited to one fish per turn regardless of their method.
4. Game 4: Pollution & Reduced Carrying Capacity – you can choose any method and switch that method after each turn, but now the fish are reproducing at 10% rather than 25% due to pollution and ocean acidification (so divide by 10 and round down instead of dividing by 4).
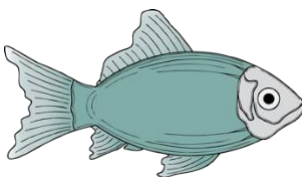
Questions: For the questions below, each person should take a turn writing an answer. The rest of the group should help develop the answers together.

1. Complete the tables below to record your results:

	Player 1 Total	Player 2 Total	Player 3 Total	Player 4 Total	Fish remaining at end of game	Winner
Game 1						
Game 2						
Game 3						
Game 4						

Player totals should be calculated by adding up the number of fish each player caught during each round. Remember, if you deplete your fish population, there is no winner for that game.

2. What method was most effective in maximizing the fish population after 10 rounds?

   _____

   Why do you think this method was more effective than all the rest? Explain:

   _____

   _____

3. What method was *least* effective in maximizing the fish population after 10 rounds?

   _____

   Why do you think this method was *less* effective than all the rest? Explain:

   _____

   _____

4. Was there at least one round where you knew that you were going to run out of fish?_____

   Why didn't you voluntarily reduce your catch to prevent your fish from running out?

   _____

   _____

5. If there were businesses that depended on fishing, how do you suppose they would be affected if the population of fish were completely eliminated? Explain:

   _____

   _____

6. What impact do you think the loss of these fish would have on the biodiversity of this area?

_____

_____

7. If these fish included a keystone species, how might the loss of this species affect the ecosystem? (Use the term *cascade effect* in your response).

_____

_____

_____

8. What kind of survivorship type would you say that these fish have? Why? How might the game change if the survivorship of the fish was changed?

_____

_____

9. How did pollution and ocean acidification affect your ability to successfully play this game?

_____

_____

10. If you had to add a player to your group (i.e. *human population growth*), how might that have affected the outcome of your game? Would you be more or less likely to avoid depleting your fish population?

_____

_____

11. Based on this game, who do you think should have the final say about the use of natural resources? Are individuals better at self-regulation, or is better to laws to regulate human behavior?

_____

_____

_____

Day 4: Review & Assessment

Directions: you will begin by reviewing the unit objectives in your small groups. For each objective, rank it as a 1 (*completely unsure*), 2 (*somewhat unsure*), or 3 (*completely sure*) based on your comfort with that objective. After a few minutes of review, your instructor will lead a whole-class review. This is your chance to ask any questions you still might have about the concepts in this unit. Begin with anything you ranked as a "1".

After you have completed the unit review, you will be taking an individual multiple choice quiz and/or a group short answer quiz. These quizzes may be graded in class to help you better understand the question and the correct answer.

Unit Objectives:
1. What is overharvesting? Does it only involve hunting or fishing?
2. Is overharvesting still occurring or was it primarily a past concern?
3. What are examples of species threatened by overharvesting?
4. How does overharvesting become more problematic if the species in question is also a keystone species?
5. What is the "cascade effect"? How does this relate to the overharvesting of keystone species?
6. How can government regulation prevent overharvesting?
7. How can scientists estimate the population of a species to determine if it is at risk of overharvesting?
8. Use the Mark-Recapture Method formula for determining the population of a species based on provided data.
9. What are "Boom and Bust Cycles"? How can this complicate the task of determining a species' population?
10. How does a species' survivorship type (Type 1, 2, or 3) affect its population management?
11. How does the carrying capacity of a species relate to population management? Are there exceptions to this?
12. What is the "Tragedy of the Commons"? How does it relate to the overharvesting of species?
13. Why does the Tragedy of the Commons occur? What are possible solutions for fixing this?

Day 5: Career Connections

Directions: Begin with a group and class discussion about the topics of this week. What is still unclear? What is still confusing? What seemed most important to remember? How does this relate to Natural Resources? How does this relate to your potential future career?

You are now at a point in the semester where you should have most of your out-of-class career experiences completed. You should meet briefly with your instructor today to discuss your progress, what you still need to accomplish, and what you have learned so far (this could be done individually or in small groups). When you are not meeting with your instructor, this would be an ideal time to complete any missing work that you may have.

If you have no missing assignments, you should try to be productive by working on projects for other classes, quietly reading, or other responsible actions. Please be sure to help your students who may have missing work by preventing distractions – they will thank you in the long run for this.

Overharvesting Individual Quiz

Name: _____ Hour_____ Date:_____ Score:_____ / _____

Directions: This quiz should be completed on an individual basis. A 3x5 notecard with handwritten notes can be used on this quiz.

1. **Which of the following best describes overharvesting?**
   a. When the loss of one species causes the extinction of a series of other species.
   b. When a species' population repeatedly exceeds their carrying capacity, causing a subsequent plummet in their population, repeating over and over.
   c. When two species occupy the same niche, one will eventually out-compete & displace the other.
   d. When more of a species is removed than can be replaced by reproduction.
   e. A situation in which people trying to gain as much individual benefit from a publicly-available resource as possible causes that resource to eventually become depleted.

2. **Which of the following best describes a Cascade Effect?**
   a. When the loss of one species causes the extinction of a series of other species.
   b. When a species' population repeatedly exceeds their carrying capacity, causing a subsequent plummet in their population, repeating over and over.
   c. When two species occupy the same niche, one will eventually out-compete & displace the other.
   d. When more of a species is removed than can be replaced by reproduction.
   e. A situation in which people trying to gain as much individual benefit from a publicly-available resource as possible causes that resource to eventually become depleted.

3. **Which of the following best describes a Boom and Bust cycle?**
   a. When the loss of one species causes the extinction of a series of other species.
   b. When a species' population repeatedly exceeds their carrying capacity, causing a subsequent plummet in their population, repeating over and over.
   c. When two species occupy the same niche, one will eventually out-compete & displace the other.
   d. When more of a species is removed than can be replaced by reproduction.
   e. A situation in which people trying to gain as much individual benefit from a publicly-available resource as possible causes that resource to eventually become depleted.

4. **Which of the following best describes Tragedy of the Commons?**
   a. When the loss of one species causes the extinction of a series of other species.
   b. When a species' population repeatedly exceeds their carrying capacity, causing a subsequent plummet in their population, repeating over and over.
   c. When two species occupy the same niche, one will eventually out-compete & displace the other.
   d. When more of a species is removed than can be replaced by reproduction.
   e. A situation in which people trying to gain as much individual benefit from a publicly-available resource as possible causes that resource to eventually become depleted.

5. **Which of the following is true?**
   a. While overharvesting used to be a significant cause of extinction, today legal protections for endangered species have eliminated this problem.
   b. Due to hunting and fishing regulations, overharvesting is rare.
   c. Overharvesting is still one of the leading causes of extinction.
   d. Overharvesting is a problem for aquatic animals but not those within the borders of countries.

6. **Briefly summarize how the effects of overharvesting are worsened if the overharvested species is a keystone species.**

_____

_____

7. **A wildlife ecologist is trying to determine the population of an endangered songbird in an area. To do so, they set up a net that safely entangles the birds until they can be banded and released. A week later, the ecologist sets up the nets again to see how many of the entangled birds are banded from the previous time. In the first round, 10 birds were caught and banded. In the second round, another 10 birds were caught and banded. Of these, five birds had a band (meaning they were caught twice). What is the population of songbirds in this area? Show you work below.**
   a. 4 birds   b. 500 birds   c. 50 birds   d. 20 birds   e. 25 birds

   Show your work:

8. **This is a method of determining population that involves collection of genetic material to determine the presence of a species.**
   a. Complete Counts   b. Incomplete Counts   c. Indirect Counts   d. DNA Testing

9. **This is a method of determining population that involves aerial surveys and visual counts.**
   a. Complete Counts   b. Incomplete Counts   c. Indirect Counts   d. DNA Testing

10. **This is a method of determining population that involves using calls, tracks, and nests determine the presence of a species.**
    a. Complete Counts   b. Incomplete Counts   c. Indirect Counts   d. DNA Testing

11. **This is a method of determining population that involves counting the number of species in a representative area and multiplying to estimate the population for the entire area.**
    a. Complete Counts   b. Incomplete Counts   c. Indirect Counts   d. DNA Testing

12. **You are trying to determine the number of pheasants in a local preserve. You set traps and capture 20 pheasants. You mark and release them. You then reset the traps and capture 20 individuals again. 10 of these are marked from your first trapping. How many pheasants are in this preserve?**
    a. 20 x 20 x 10 = 4000
    b. 10 ÷ 20 x 20 = 10
    c. 20 x 20 ÷ 10 = 40
    d. 20 x 10 ÷ 20 = 10

13. **You are trying to determine the number of walleye in a local lake. You set capture 7 walleye and notch their fins. You release them and return a week later. You catch 10 fish, of which 4 have notched fins. How many walleye are in this lake?**
    a. 10 x 4 ÷ 7 = 5 or 6 walleye
    b. 10 x 7 ÷ 4 = 17 or 18 walleye
    c. 7 x 4 ÷ 10 = 2 or 3 walleye

14. **A large ocean fish (Species A) does not reproduce until it is 10 years old. When it does reproduce, it produces a small number of eggs. Most of these survive to adulthood.**

   Another large ocean fish (Species B) reaches reproductive capacity within two years. It produces large amounts of eggs, most of which do not survive to adulthood.

   Which species has a Type 1 survivorship? Which has Type 3? Which is at greater risk for extinction from overharvesting?
   a. Species A has a Type 1 survivorship, and Species B has Type 3. Species A is at more risk.
   b. Species A has a Type 3 survivorship, and Species B has Type 1. Species A is at more risk.
   c. Species A has a Type 1 survivorship, and Species B has Type 3. Species B is at more risk.
   d. Species A has a Type 3 survivorship, and Species B has Type 1. Species B is at more risk.

15. **Species X is moderately endangered, while Species Y is a greater risk for extinction. Species X is a keystone species; species Y is not. Which species is a higher priority for protection?**
   a. Species Y should be a higher priority because it is more endangered.
   b. Species X should be a higher priority because it would cause more additional extinctions if lost than Species Y.
   c. Both species should get equal priority for protection.

16. **Which of the following could be an example of Tragedy of the Commons?**
   a. When everyone decides it is more convenient to drive alone than to carpool or take mass transit, traffic jams become more common and roads become more damaged in unusable.
   b. If everyone exceeds the fishing limits by even a small amount, it can cause the entire fish population to collapse.
   c. When ranchers over-graze their cattle on public land, it can cause the grassland ecosystem to collapse and become depleted.
   d. All of the above could be examples of Tragedy of the Commons because they involve the depletion of a publicly available resource due to individuals maximizing their personal gain.

17. **How can we prevent the overharvesting of endangered species as a result of Tragedy of the Commons? List & describe three ways in which TOC can be stopped in the space below:**

   1. _____

   _____

   2. _____

   _____

   3. _____

   _____

Overharvesting Group Quiz

Names (F&L): _____

_____ Hour_____ Date:_____ Score:_____ / _____

Directions: This quiz should be completed in your assigned groups. A 3x5 notecard with handwritten notes can be used on this quiz. Each person should take turns writing an answer. Those not writing should be actively working together to create their group's answer. Those who are not actively involved in answering every question may be asked to complete this quiz alone. Record the writer's name after each question.

1. **In the space below, define "overharvesting" and provide examples. Then explain how and why species can be harvested to the point of extinction. In particular, address why it is that humans will continue to utilize a resource even as it is obviously becoming depleted.**

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Writer's Name:

2. **Many overharvested species are apex predators and/or keystone species. Past and current examples include the American bison, tigers, and sharks. In the space below, explain why overharvesting of an apex predator or keystone species would be especially harmful to an ecosystem using an example. Include a definition of the term "cascade effect" in your response.**

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Writer's Name:

3. **In order to determine if a species requires legal protections, scientists must have a general understanding of the level and trends in that species' population. In the space below, describe the various options for how a population level of a species can be determined. Also, be sure to provide an explanation for when a species *should* have a low population, and address when a species should get highest priority for protection.**

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Writer's Name:

4. **Imagine a hypothetical situation in which a heated public debate is occurring over whether or not to allow the hunting of grizzly bears in a national park. Advocates for a hunting season are arguing that the bear population was at one of its highest recorded levels only a year ago, which is enough to warrant a hunting season.**

   However, a number of wildlife ecologists have suggested that a bear hunting season in this area would be a poor choice. They argue that the bear population was at its peak in a boom and bust cycle last year, and now that their prey is depleted, they are in the midst of a significant population decline. Furthermore, the bears are an apex predator and are potentially a keystone species; the harm that could be caused if their population declines too much would be significant. They also note that the bears in this area have a Type 1 survivorship pattern, with comparatively low reproductive rates compared to other game species but high rates of offspring survival. The scientists have argued that a hunting season should at least be postponed until their population recovers from the boom and bust cycle.

   As a wildlife expert, you have been asked to make a comment about what to do. What would you decide? Be sure to explain the following in your response: Boom & Bust Cycle, impact of overharvesting of apex predators or keystone species, and Type 1 Survivorship.

   _____

   _____

   _____

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   _____

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   _____

Writer's Name:

5. **While pollution of land and smaller bodies of water has been reduced over recent decades, plastic pollution in the ocean and atmospheric carbon pollution have been measurably increasing at a faster rate. Why would it be easier to prevent land and freshwater pollution than it would be to stop ocean and atmospheric pollution? In your answer, be sure to address Tragedy of the Commons and the three reasons why it occurs. Be sure to also provide possible solutions to this problem OR if you cannot, explain why there are no easy solutions to this problem.**

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Writer's Name:

Appendix: Data Dives / Case Studies

Overview: Data Dives and Case Studies are exercises in which students are presented with data from experiments or scenarios, and are asked to identify trends and develop explanatory models in a process that is very similar to what actual scientists do on a regular basis.

Directions: Students should consider the data or scenario in their assigned groups. They should work with their group members to make sense of the information provided and try to determine the conclusions that can be drawn from it. Students may struggle with this, especially in their first attempts and particularly if your students have limited experience reading graphs and data tables. It may be necessary for you to project the data onto a large screen and guide students by explaining the steps that you would use to make sense of what is being reported. This may be difficult; just like explaining the steps of tying your shoes can be challenging because you rarely have to think about it, it can be exceptionally challenging for someone who is scientifically literate to identify the thought processes that they use to make sense of data. It may be helpful to jot down your ideas in advance and have them ready prior to the start of this class.

Students are likely to struggle to varying extents. That is ok! Be sure to float from group to group to assist. Be sure to remind group members to help each other out. It might ideal to assign groups with a mix of abilities. Encouraging struggling students to work with their better-prepared peers, and conversely, encouraging high performing students to advance their abilities by working with individuals with different skill sets helps to prepare students for the kinds of situations they will encounter in their careers and personal lives. Plan to allow for about 15-20 minutes to introduce the activity and review how to interpret this information with your students. About a third to half of the class period should be reserved for allowing students to work in their individual groups. The remaining time should be reserved for intergroup or whole-class discussion so that students can engage in scientific debate and argumentation.

It would a good idea to remind students that the term *argumentation* is used differently between scientists and the general public. While argumentation generally has a negative connotation (such as a "heated argument"), argumentation among scientists is generally very good-natured and polite. The goal is not to "win" an argument but rather to expand the understanding of the phenomenon by all involved. Often scientists on opposing sides of an issue will both change their stance as a result of the improved understanding that results from engaging in argumentation. Similarly, students should not be trying to disprove each other or prove that they have the "right" answer. Rather, students should be examining the differences in their conclusions, the manner in which each conclusion was reached, and the similarities and agreements that exist among different conclusions.

Students may reach a conclusion that is not entirely supported by evidence. The temptation may be to point out errors in their reasoning. However, when students are struggling, they are also likely improving their abilities in evidence-based reasoning, which is one of the most important goals of this kind of instruction. Try to resist the urge to correct student errors; rather, try to probe their understanding and challenge them to re-examine the evidence to check the validity of their conclusions and the conclusions of other groups. Consider using the 9 Talk Moves (next page) to support productive classroom dialogue. Remember – students should re-visit their explanations and models repeatedly over the course the week. If they don't get it right on the first try, they will have more opportunities to do so.

Note: students could legitimately question some sources of this data as being potentially biased. While more reliable sources of data exist, their presentation of this data was less accessible to a high school audience. The data provided in this exercise align with that provided in peer reviewed sources from more reliable origins. We have chosen to utilize this source's data as a necessary compromise between accessibility and reliability.

Goals for Productive Discussions and Nine Talk Moves

Goal: Individual students share, expand and clarify their own thinking

1. Time to Think:

Partner Talk

Writing as Think Time

Wait Time

2. Say More: "Can you say more about that?" "What do you mean by that?" "Can you give an example?"

3. So, Are You Saying…?:

"So, let me see if I've got what you're saying. Are you saying…?" (always leaving space for the original student to agree or disagree and say more)

Goal: Students listen carefully to one another

4. Who Can Rephrase or Repeat?

"Who can repeat what Javon just said or put it into their own words?" (After a partner talk) "What did your partner say?"

Goal: Students deepen their reasoning

5. Asking for Evidence or Reasoning:

"Why do you think that?" "What's your evidence?" "How did you arrive at that conclusion?" "Is there anything in the text that made you think that?"

6. Challenge or Counterexample:

"Does it always work that way?" "How does that idea square with Sonia's example?" "What if it had been a copper cube instead?"

Goal: Students think with others

7. Agree/Disagree and Why?:

"Do you agree/disagree? (And why?)" "Are you saying the same thing as Jelya or something different, and if it's different, how is it different?" "What do people think about what Vannia said?"
"Does anyone want to respond to that idea?"

8. Add On:

"Who can add onto the idea that Jamal is building?"
"Can anyone take that suggestion and push it a little further?"

9. Explaining What Someone Else Means:

"Who can explain what Aisha means when she says that?" "Who thinks they could explain in their words why Simon came up with that answer?" "Why do you think he said that?"

Source: https://inquiryproject.terc.edu/shared/pd/TalkScience_Primer.pdf

Appendix: The Fishing Game

Overview: In this activity, students will be taking part in a simulation of the factors that lead to the Tragedy of the Commons.

Materials: the packet; game pieces that will represent "fish", such as poker chips, paper clips, scraps of paper, pennies, or anything of that nature. Groups will about 60 pieces each to be safe.

Directions: see the packet for detailed instructions. In short:
- Each group starts with 20 "fish" in their ocean (the surface of a desk works fine).
- Each student can harvest fish based on the rules of each of the four games. Whether or not they can change their method (and the number of fish caught) depends on the rules of each of the four games.
- After each student has collected their fish, the fish need to reproduce. Take the number remaining, divide by four, and add that number to the ocean (if not a whole number, round down to the next whole number – e.g. 3.5 = 3).
- There are two goals: to collect as many fish as possible on an individual basis and to have as many fish remaining at the end of the game as possible. If the fish population reaches zero, everyone loses.

Note: using pieces of candy as your "fish" can add an extra incentive for your students but may not be appropriate for all classes or situations. Check the safety regulations of your school and department first.

Appendix: Review and Asssessment

Introduction: In this section, we will discuss strategies to guide your students during review and assessment for a vocabulary-intensive unit.

While recent reforms to science education (as outlined by the NRC's *K12 Framework* and NGSS) minimize the emphasis on having students learn vocabulary, we have found that we cannot completely eliminate vocabulary from ecological instruction for a number of reasons. Most importantly, we have found that in order for students to sufficiently engage in reasoning and sense-making about ecological phenomena, they need to have an appropriate language with which to develop explanations and solutions.

However, in the FACTS curriculum, we view vocabulary as a *means to an end* and not as a central objective to the curriculum. In other words, we don't care very much whether students have memorized the definitions of terms, but whether they can accurately use those terms to describe and understand phenomena, and ultimately create evidence-based arguments, explanations, and solutions. We view vocabulary as part of a "sense-making toolkit" that enables students to organize their reasoning and argumentation.

As such, we recommend that you provide students with opportunities to practice mastering the vocabulary in this course while also recognizing that mastery of vocabulary is a secondary objective in these units. This means that assessing vocabulary can work as a formative assessment but is not ideal by itself as a summative assessment. The primary goal of this curriculum is to enable valid evidence-based reasoning and sense-making, and your summative assessments should reflect this.

There are a few strategies you might considering adopting to support these objectives:
- While multiple-choice assessments are provided in the weekly packets, we take the stance that these options should not be used by themselves as a final summative assessment.
    - You might consider assigning this as optional homework, allowing students to use a 3x5 card with handwritten notes, and/or assigning completion points in lieu of scores based on the percent correct.
- Teachers have also created hybrids of the multiple choice and short answer assessments, selecting some questions from each option. Their experiences suggest that the multiple-choice assessments help to prepare students for the more intellectually rigorous short answer questions.
- You might also consider having a space on a chalkboard/dry-erase board for publicly posting course vocabulary or hanging a large sheet of paper and adding vocabulary and definitions if students start to struggle.
- Teachers have also used vocabulary practice as an option for a bell-ringer activity, using options such as short, ungraded online quizzes to start class.

You as the instructor are best positioned to decide what will be most effective for your classroom. Feel free to use or disregard these suggestions as you see fit. However, we do strongly recommend that you avoid positioning memorization of vocabulary as one of the primary objectives of this course, and instead emphasize valid reasoning and sense-making about ecological phenomena as your top priority.