**Overview**

Students explore the effect of modern agriculture practices on trophic cascades using species associated with rice cultivation. The activity is run as a jigsaw, with four of the worksheets serving as individual case studies examining one aspect of rice agriculture related to the trophic cascade involving nutrients -> rice -> brown plant hoppers -> spiders. Expert groups then break into new jigsaw groups to teach their case study to other students. The final worksheet stimulates a large-group discussion about how each of the case studies are related to one another. This case study in regulation at the community level was inspired by the description of this system in *The Serengeti Rules* by Sean B. Carroll (p. 158-161).

**Key Concepts**

* Trophic cascades
* Top-down and bottom-up regulatory mechanisms
* Modern agricultural effects
* Predator-prey interactions
* Lotka-Volterra predator-prey model

**Student Learning Targets**

* Describe how trophic cascades regulate population density of the species involved.
* Describe the trophic cascade in the case of rice/herbivory/predator chain.
* Interpret data presented in figures.
* Build graphs using raw data.
* Model interspecific interactions

**Key terms**

Agriculture, consumer, ecosystem, herbivore, predator, producer, trophic cascade, trophic chain, trophic level, trophic web.

**Time Requirements**

**In Person Course**

* 30 minutes: Read the worksheet, answer follow-up questions. *Could be given 1-2 class periods beforehand to be completed as homework.*
* 15-20 minutes: Work with group members in their Expert group (those with the same case study) to double check answers to the questions and to work together to create a concise summary to share with other groups.
* 40 minutes: Mix students into Jigsaw groups, with at least one member of each Expert group, to go over main ideas from each case study and answer follow-up discussion questions
* 20 minutes: Class discussion, jumping group to group about discussion questions

**Online Course**

* 1 week for students to work in their Expert group on the discussion questions
* 1 week for students to work in their Jigsaw group to write a summary of their case study and to answer group discussion questions

**Suggested audience**

* College level introductory biology: food webs
* College level environmental biology: food webs, agriculture
* College level general ecology: food webs, predator-prey

**Prior Knowledge**

Students should

* Be able to explain what is an ecosystem and its components.
* Be able to explain positive and negative feedback regulation.
* Be able to explain what are trophic levels and cite examples.
* Be able to explain what is a trophic chain and a trophic web.
* Be able to explain the elements of the Lotka-Volterra model

**Materials**

* Before completing the exercises below, students can complete an online click-and-learn activity on trophic cascades: <https://www.hhmi.org/biointeractive/exploring-trophic-cascades>
* Individual case study worksheets (there are 4, each student will get 1 of the 4).
* Group discussion questions (1 per student).
* Students may benefit from access to the internet for accessing research materials and other relevant to the content.
* Signs around the room to place students into their expert groups (4 signs needed, one for each expert group)
* Post-its or similar to assign “experts” into their jigsaw groups

**Background**

Nine of the top ten world rice producers are in Asia with, China producing 35% of the world’s rice. Over 30% of the calories consumed in Asia come from rice. Rice has been cultivated in Asia for more than 6,000 years. During the “green revolution” of the 1960s, farmers began introducing artificially selected high yield rice varieties, combined with the use of pesticides and fertilizers. The goal was to avert the threat of famine due to crop failure and a booming population. In less than ten years a quarter of all farms were using the new rice varieties and many farmers in Asia saw their rice yields per acre almost double. In the 1970s many of these farms began to see their rice paddies turning orange-yellow and then brown. The culprit was a tiny insect called the brown planthopper (BPH). Although just a few millimeters long their females put out hundreds of eggs that hatch tiny nymphs that feed on the sap causing the rice leaves to turn yellow and then die. Naturally the first instinct of the farmers was to apply even more pesticide but the outbreak continued and even worsened.

**Teaching Tips**

* For the first classroom meeting, take the number of students and divide by 4, round up and print this many copies of each of the case studies (each student will only get one worksheet). For the second classroom meeting, place sheets around the room denoting each of the 4 groups for students to easily find their Expert group. Print group discussion questions worksheet for each student.
* Suggested student grouping -- Students can randomly choose one case study worksheet to take or the instructor can assign students to a particular group. In creating the jigsaw groups, assign students in the expert group a new unique number. This number will correspond to their new group. If you have an uneven number of students, assign two students in the same Expert group to go to the same Jigsaw group.
* For an online course: Place students into formal groups in the LMS with a pre-made discussion board for each of the discussion questions from their case study. When creating the jigsaw groups in your LMS, have multiple people from each expert group in the Jigsaw group in case a student or two do not check in with the activity.
* Suggested assessments: Use one of the graphs from one of the groups on a test and ask them similar questions to those addressed during the discussion. Create multiple choice questions that assess the knowledge from the various case studies.

**Answer Key**

As students work in their jigsaw groups, the key takeaways that each “expert” should be sharing with their peers is:

* **Group 1 - Effects of Fertilizer**: Nutrients are not only beneficial for rice and other plants, they are also directly useful in insects and other herbivores. For example, a lack of nitrogen used on plants resulted in a decrease in brown plant hopper (BPH) feedings. Nutrients, particularly nitrogen and potassium, also lower the plants defenses by lowering Si content which increases BPH infestations.
* **Group 2 - Predator/Prey Interactions**: Despite pesticides eradicating pests initially, brown planthoppers return as the pesticides also kill their natural predators in their ecosystem. Students have difficulty with the second graph, mostly due to misunderstanding the y-axis. Students commonly thought the y-axis portrayed numbers of organisms that died, versus lethal concentration. Endosulfan is one of the best choices for a pesticide because a small amount can kill a majority of the BPH without affecting their predator, mirids.
* **Group 3 - Pesticide Resistance:** Although initial pesticide application can diminish a population, pest populations recover due to selecting forces by the pesticide. This pesticide resistance is a major contributor to the rapid development of new pesticides on the market.
* **Group 4 – The Use of Cultivars:** Many students incorrectly think cultivars are gmos. Cultivars are choosing traits that are present in the population whereas GMOs are are choosing traits and genes from other species to insert into the host organism. Cultivars are widely used in agriculture and have been responsible for growing yields in rice. Similar to the active use of pesticides, cultivars can contribute to resistant pests, which is why it is recommended that cultivars be planted in mix fields with non-pest resistant cultivars.

**Optional Extensions**

An adaption to this exercise for an upper division ecology course can be found as a separate exercise. The adaptation includes the use of a Lotka-Volterra predator-prey simulation where students explore the effects of bottom-up and top-down ecosystem level processes on the population density of BPH and its predators Increases or decreases of BPH due to nutrient availability, or pesticide resistance or type of cultivar translates into changes in ***rprey,*** percapita rate of increase, of the prey in the model, which in turn may lead to increases in density of the predator, i.e. spiders and other insects (***c\*Nprey\*Npredator)***. A second extension includes a further analysis of pesticide resistance in brown planthoppers.

**References**

Bottrell, D. G., & Schoenly, K. G. (2012). Resurrecting the ghost of green revolutions past: The brown planthopper as a recurring threat to high-yielding rice production in tropical Asia. *Journal of Asia-Pacific Entomology, 15*(1), 122-140.

Carrol, B. (2016). *The Serengeti rules: The quest to discover how life works and why it matters.* Princeton, NJ: Princeton University Press.