NATURE LAB Educator Resources

BEE DETECTIVE:
DISCOVER THE CULPRIT BEHIND DECLINING BEE POPULATIONS

Subject Area: Science – Food Webs

Grades: 6th – 8th

Time: This lesson can be completed in two 45 minute sessions.

Essential Question:

- What are the possible causes behind the collapse of bee colonies?

Overview:

Students learn about the features of a honeybee colony and the potential causes of colony collapse disorder (CCD). Students explore and "report" back to the queen bee (teacher) with possible causes of CCD.

Themes:

Bees produce honey, a widely used ingredient in some foods.

Beeswax has a wide range of domestic and industrial uses. The practice of beekeeping goes back to antiquity.

Introduction:

In this lesson plan, students study the widely reported loss of bees declining because of colony collapse disorder (CCD). Since bees provide vital benefits to people, including crop pollination, and products such as honey and beeswax, the loss of bee colonies through CCD is a serious concern.

The activity puts students at the cutting edge of science research because to date, CCD has not been reliably attributed to any single cause. The aim is for students to understand that in nature,

simple cause-effect relationships may not explain all our observations. In this way, students learn that science is an investigative process, not simply a way to describe nature.

Thus, a variety of clues are presented that lead students to conclude that CCD results from a combination of factors. To make the activities more engaging, the students can play the role of worker bees. The teacher is the queen bee. The worker bees report the results of their research to the queen. If needed, review the roles of the different castes in the bee colony. Key points:

- The queen lays eggs and provides chemical cues to direct the colony's behavior. If the queen dies, the colony cannot survive.
- The workers are all sterile females and perform all the chores of the colony such as tending larvae, getting food for the colony, building the wax honeycombs and defending the colony.
- Drones are males and their only role is to mate with new queens so that the colony can reproduce.

Scientific findings to date suggest that external factors prevent workers from returning to the hive, which is the proximate cause of CCD. Related or causal factors include:

- Bees bring back pollen treated with chemicals, bacterial infections, fungus or mites from nearby colonies. Such pollen serves as a vector for disease or toxins within the hive.
- A loss of habitat can result in malnutrition for larvae, such as mineral deficiencies.
- Infection of bees with the Varroa mite (which feeds off the lymphatic tissue of adult bees) is implicated in many, but not all, cases of CCD.
- Some studies suggest that electromagnetic radiation interferes with a bee's navigation, preventing them from returning to the hive. Therefore, the increase in cell-phone use may be a cause of CCD.

Key statistics related to CCD (to use in lesson)

- U.S. beekeepers lost more than a third of all their hives in the three years from 2006 to 2009.
- Honey bees are the main pollinators of agricultural crops, providing pollination for crops valued at up to $20 billion annually.
- About a third of the U.S. diet comes from foods that involve pollination by honey bees.
- Beekeepers normally lose some colonies, but the recent declines are much greater than in previous years.
- Colony failure in recent years is characterized by bees failing to return to hives, but this behavior is abnormal and its cause is unknown.
- CCD has been reported in more than 35 states and many other countries.

Objectives:

The student will…

Knowledge

- Describe key features of honey bee behavior and biology, and identify causes of CCD.
- Know that honeybees benefit humans in the following ways:
    - Important pollinators of food crops.
    - Producers of honey and beeswax.
    - A tradition of bee-keeping dating back thousands of years.

Comprehension

- Predict likely impacts of CCD on benefits bees provide to humans such as crop pollination and production of honey bee products.

Application

- Hypothesize possible causes of CCD based on knowledge of bee behavior and biology.

Analysis

- Illustrate bee behavior as it relates to causes of CCD.

Synthesis

- Organize possible causes of CCD by likelihood.

Evaluation

- Communicate the impact of CCD on the benefits bees provide to people such as reduced pollination of agricultural crops and increased crop prices, and various bee products.

Standards:

Next Generation Science Standards

Disciplinary Core Ideas

- LS1.B Growth and Development of Organisms
- LS2.C Ecosystem Dynamics, Functioning, and Resistance
- LS4.B Natural Selection

Crosscutting Concepts

- Causation
- Patterns
- Stability and Change
- Systems

Science and Engineering Practices

- Asking Questions/Defining Problems
- Constructing Explanations
- Arguing from Evidence
- Communicating information

Performance Expectations Middle School

- MS-LS1-4 Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.
- MS-LS1-5 Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.
- MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
- MS-LS4-4: Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment.
- MS-LS4-5: Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms.

Common Core English and Language Arts Standards for Science and Technical Subjects and Writing Grades 6-8

- CCSS.ELA-LITERACY.RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts.
- CCSS.ELA-LITERACY.RST.6-8.2 Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.
- CCSS.ELA-LITERACY.WHST.6-8.8 Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.
- CCSS.ELA-LITERACY.WHST.6-8.9 Draw evidence from informational texts to support analysis, reflection, and research.
- CCSS.ELA-LITERACY.WHST.6-8.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

Vocabulary:

Apiary: A group of beehives cared for by an apiarist.

Colony collapse: Sudden demise of a honeybee colony.

Eusociality: Social behavior among a group of related organisms in which nonbreeding individuals care for young.

Mite: A tiny arachnid with four pairs of legs, related to spiders.

Pollinator: Organism such as a honeybee that visits flowers, resulting in pollination.

Materials:

Videos that support this lesson plan:

- *Pollinators – Putting Food on the Table* introductory video -http://vimeo.com/77811127
- close-up of bees entering a hive - http://vimeo.com/39224539
- interior of hive - http://vimeo.com/39224562

For each group of students:

- Computer with Internet connection (or can be executed with one computer and interactive board in the class)
- Printouts of media articles related to CCD (see below)

Media articles (print out for lesson or have students read online):

- http://money.cnn.com/2007/03/29/news/honeybees/
- http://www.dailymail.co.uk/sciencetech/article-1385907/Why-mobile-phone-ring-make-bees-buzz-Insects-infuriated-handset-signals.html
- http://www.spiegel.de/international/world/0,1518,473166,00.html
- http://news.bbc.co.uk/2/hi/science/nature/8467746.stm
- http://www.sciencedaily.com/releases/2005/05/050517110843.htm
- http://www.planetark.com/dailynewsstory.cfm/newsid/43163/story.htm
- http://articles.latimes.com/2007/apr/26/science/sci-bees26
- http://www.nytimes.com/2007/09/07/science/07bees.html

Classroom Activities:

Part 1: Engage

1. Bring a variety of fruits such as apples, pears and cherries, and nuts* to class. (*Use photos of nuts if regulations do not permit nut products in school.)

2. Bite into an apple, and ask students how an apple grows.

3. Show students the introductory video *Pollinators – Putting Food on the Table* that demonstrates how a picnic would be thin fare without bees.

4. Lead students to the conclusion that apples and many fruit crops grow on trees from flowers pollinated by bees. This will emphasize the importance of bees to agriculture in their role as *pollinators*.

5. Use the whiteboard to help students complete a list of how bees are vital to the ecosystem. Possible reasons include:
   - Bees depend on flowers and the plant's existence in turn depends on bees.
   - When bees get pollen and nectar from flowers, they pollinate or fertilize the plant. Plants then can produce their own fruits and seeds.
   - Bees are the primary or only source of pollination for many plants.
   - Fruits resulting from pollination by bees are consumed by many birds, insects and other animals.
   - Honey is food for wild animals

6. Tell students that a place where bees are raised is called an *apiary*, where beehives are cared for by an *apiarist*.

7. Show video of bees entering hive and interior of hive.

8. Present statistics highlighting *colony collapse* disorder, such as U.S. beekeepers losing more than a third of all their hives in 2007. Similar problems are reported from Europe and elsewhere.

9. Have students brainstorm to list crops pollinated by honeybees, evaluate the consequences of such losses, and thereby see the urgency of understanding the causes of CCD.

Part 2: Explore

1. Students investigate possible causes of CCD by learning about honeybee biology and ecology. Have students learn about:
    a. Hive activities including social behavior, caste structure (workers, queen, drones), hive management and honeycomb architecture.
    b. Pollination activity including visiting flowers
    c. Environmental factors related to mortality including predators, temperature, exposure to radiation (cell phones) and pesticides

2. Have the class brainstorm to list factors that cause the death of honeybees.

3. Encourage students to hypothesize on factors that could lead to CCD, i.e., higher death rates than usual (for example, predators are an unlikely cause of CCD since there is no evidence the number of predators has increased).

4. Have them make a list of possible causes of CCD based on causes of bee death.

5. Divide students into small groups. Each group must choose one possible cause from the list in Step 5 as a hypothesis and then test the hypothesis with evidence from the literature. Give each group access to the media articles and online resources on honeybee biology.

6. Have each group present the results of their findings to the class.

7. In particular, encourage students to discuss *mites* as a cause of CCD, since these are implicated in many incidents of CCD.

8. Have each group of students hypothesize the relative importance of each factor. For example, cell phone use might be a less important cause in areas where there are few cell phones, compared to use of pesticides, which are widely used. The job of each group is to develop a ranked list of possible causes from most to least likely.

9. Have groups report to the teacher with their compiled list of possible causes.

10. The students can help the teacher to compile each of their lists to see where there is consensus, and to develop an overall ranked list.

11. Have students use the whiteboard to create their list of possible causes of CCD and hypothesize on the likelihood of each factor being the cause of CCD based on their investigation in the Explore section. (Don't worry if they don't emerge with one single answer. The causes of CCD are still unclear. The aim is to help them think critically about evaluating possible causes.)

12. Have students rank the likelihood of possible causes based on the consensus list (Step 10 above).

Part 3: Explain

1. Have students research the concept of *eusociality*, so that they can explain that honeybees are social insects with colonies comprising numerous non-breeding individuals that take care of young as directed by a breeding female.

2. Ensure that students can describe how bees are vital to natural ecosystems and human agriculture. Students should be able to make the connection that future production of many crops as well as wild plant communities depends on the health and sustainability of bee colonies.

3. Students should be able to articulate that if we can understand the causes of CCD, we can implement measures to ameliorate the impact of honeybee population declines.

4. Have students discuss the list of possible causes of CCD and hypothesize on most likely scenarios based on their investigation in the Explore section.

5. Have students rank the likely impact of possible causes based on the consensus list (Step 10 in the Explore section).

Part 4: Extend

1. Have students read the printouts of media articles and review them to relate their possible causes of CCD with those that are reported in the media.

2. Discuss the role of genetics as a factor. For example, colonies derived from a single ancestral colony may be equally susceptible to diseases or parasites. Colonies derived from crossing unrelated ancestral colonies may be less susceptible to diseases or parasites.

3. Have students hypothesize possible solutions to each of their selected factors.

4. Have students brainstorm other industries that are impacted by loss of honeybees, such as beeswax and honey production.

5. Have students create a short article for a school or local website that highlights the benefits of honeybees and the threat of CCD.

6. Have students research to find the earliest recorded beekeeping in history. Another exercise could include finding mentions of beekeeping in popular literature (such as Sherlock Holmes retiring to a life as a beekeeper) and other notable mentions of beekeeping, bees or honey (see Additional Resources).

7. Students could visit a local apiarist to learn firsthand the challenges of beekeeping.

8. Have students create a concept map of how bees benefit wild plant communities, such as pollinating rare or endangered plants.

Part 5: Evaluate

Students will be evaluated on the quality of their ideas, and their ability to attribute a cause. The aim is for students to discern that there sometimes is no simple answer to explain a biological observation. Specific questions:

1. Why will a decline in the number of bees affect the health of the bee colony?

2. What will be the effect on yields of food crops such as fruits and nuts if the number of colonies declines? Explain.

3. How is the decline of bees likely to affect the prices of fresh fruits and other foods in the supermarket?

4. If a bee colony with 50,000 bees loses 30 percent of its bees during one winter, how many bees will *survive* that winter?

5. Draw a simple graph to estimate how long it would take for the bee colony to collapse completely (less than 10,000 bees) if it lost 30 percent of its bees every winter, and gained only 5 percent each spring.

Scoring key for evaluation

1. If the number of bees declines, there are fewer workers to bring food to developing young. The queen can continue to lay eggs, but fewer larvae will mature. Such a colony is less able to survive natural fluctuations in worker numbers caused by cold weather, and by hive pests or parasites.

2. If the number of colonies declines, fewer flowers will be pollinated. This, in turn, means that plants will form fewer fruits. Yields of food crops will be lower as a result.

3. If bees decline, crop harvests are lower so there is less food available for sale. Therefore prices of fresh fruits and other foods in the supermarket will increase.

4. Since 30% of 50,000 = 15,000, the number of surviving bees = 35,000 bees.

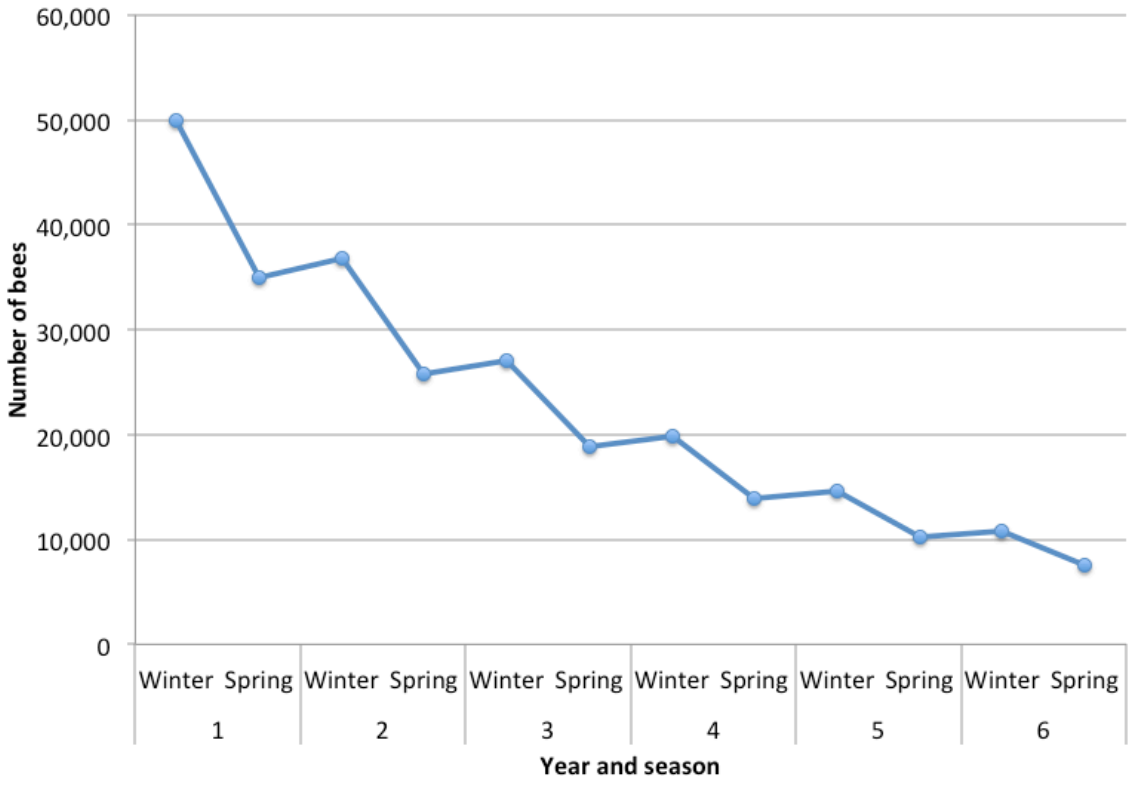
5. Students should create a simple table as follows. Have students program formulas into a spreadsheet:

    a. Loss = number of bees in winter x 30%
    b. Gain = number of bees in spring x 5%
    c. Number of bees in winter = Number of bees in spring + gain (except winter in year 1)
    d. Number of bees in spring = Number of bees in winter - loss

Therefore it would take **6 years** for the colony to collapse to less than 10,000 bees.

Year	Season	Number of bees	Loss	Gain
1	Winter	50,000	15000	
	Spring	35,000		1750
2	Winter	36,750	11025	
	Spring	25,725		1286
3	Winter	27,011	8103	
	Spring	18,908		945
4	Winter	19,853	5956	
	Spring	13,897		695
5	Winter	14,592	4378	
	Spring	10,215		511
6	Winter	10,725	3218	
	Spring	7,508		375

EXAMPLE GRAPH



Additional Resources and Further Reading:

Websites

- Learn how bees play an important role in agriculture
  http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/indiana/journeywithnature/bees-agriculture.xml

- Honey Bee Colony Collapse Disorder – Congressional Research Service
  http://www.fas.org/sgp/crs/misc/RL33938.pdf

- National Honey Board Website
  http://www.honey.com/

- Bee-keeping in Ancient Egypt
  http://reshafim.org.il/ad/egypt/timelines/topics/beekeeping.htm

- Bee Culture – The Magazine of American Beekeeping
  http://www.beeculture.com/content/StateApiaristDirectory/

- USDA Honey Bee Research
  http://www.ars.usda.gov/main/site_main.htm?modecode=53-42-03-00

- Bad Beekeeping: The Beekeeper's Home Pages
  http://www.badbeekeeping.com/fame.htm

Journal Articles

- N. Gallai, J. Sales, et al. 2009. Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. Ecological Economics 68: 810-821

- Roulston, T. and K. Goodell (2011) The Role of Resources and Risks in Regulating Wild Bee Populations. Annual Review of Entomology 56: 293-312. DOI: 10.1146/annurev-ento-120709-144802