**Subject area/course**: Science/Biology; Mathematics/Algebra II

**Grade level/band**: 10-11

**Task source**: Achieve

**Honey Bee Colony Analysis**

**TEACHER'S GUIDE**

1. **Task overview**:

In this task, the students mathematically model changes in the bee colony numbers from the United States and from two individual states, California and South Dakota. Students then use their constructed mathematical models to describe factors affecting the bee colony populations. The students choose function(s) that best fit the data, both the whole dataset and a subdivided data set. Based on trends identified by the models, students also consider how changes in bee colony numbers might affect the overall stability and biodiversity of ecosystems in which the honeybees participate. Finally, students evaluate a proposed solution for CCD using a set of criteria and constraints.

1. **Aligned standards:**
2. **Common Core State Standards**

[CCSS.Math.Practice.MP2](http://www.corestandards.org/Math/Practice/MP2/)Reason abstractly and quantitatively.

[CCSS.Math.Practice.MP3](http://www.corestandards.org/Math/Practice/MP3/) Construct viable arguments and critique the reasoning of others.

[CCSS.Math.Practice.MP4](http://www.corestandards.org/Math/Practice/MP4/) Model with mathematics.

[CCSS.Math.Content.HSF.LE.A.1](http://www.corestandards.org/Math/Content/HSF/LE/A/1/) Distinguish between situations that can be modeled with linear functions and with exponential functions.

[CCSS.Math.Content.HSF.LE.B.5](http://www.corestandards.org/Math/Content/HSF/LE/B/5/) Interpret the parameters in a linear or exponential function in terms of a context.

[CCSS.Math.Content.HSS.ID.B.6](http://www.corestandards.org/Math/Content/HSS/ID/B/6/) Represent data on two quantitative variables on a scatter plot, and describe how the variables are related.

[CCSS.Math.Content.HSS.IC.B.6](http://www.corestandards.org/Math/Content/HSS/IC/B/6/) Evaluate reports based on data.

[CCSS.ELA-Literacy.RST.11-12.2](http://www.corestandards.org/ELA-Literacy/RST/11-12/2/) Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

[CCSS.ELA-Literacy.RI.11-12.7](http://www.corestandards.org/ELA-Literacy/RI/11-12/7/) Integrate and evaluate multiple sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a question or solve a problem.

[CCSS.ELA-Literacy.RST.11-12.7](http://www.corestandards.org/ELA-Literacy/RST/11-12/7/) Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

[CCSS.ELA-Literacy.RST.11-12.9](http://www.corestandards.org/ELA-Literacy/RST/11-12/9/) Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

[CCSS.ELA-Literacy.W.11-12.9](http://www.corestandards.org/ELA-Literacy/W/11-12/9/) Draw evidence from literary or informational texts to support analysis, reflection, and research.

1. **Critical abilities**

Research: Conduct sustained research projects to answer a question (including a self-generated question) or solve a problem, narrow or broaden the inquiry when appropriate, and demonstrate understanding of the subject under investigation. Gather relevant information from multiple authoritative print and digital sources, use advanced searches effectively, and assess the strengths and limitations of each source in terms of the specific task, purpose, and audience.

Analysis of Information:Integrate and synthesize multiple sources of information (e.g., texts, experiments, simulations) presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to address a question, make informed decisions, understand a process, phenomenon, or concept, and solve problems while evaluating the credibility and accuracy of each source and noting any discrepancies among the data.

Communication in Many Forms:Use oral and written communication skills to learn, evaluate, and express ideas for a range of tasks, purposes, and audiences. Develop and strengthen writing as needed by planning, revising, editing, and rewriting while considering the audience.

1. **Next Generation Science Standards**

Scientific Practice: Scientific Argumentation: Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (HS-LS2-i),(HS-LS2-k)

[HS-LS2-2.](http://www.nextgenscience.org/hsls2-ecosystems-interactions-energy-dynamics) Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.

[HS-ETS1-3.](http://www.nextgenscience.org/hs-ets1-3-engineering-design) Evaluate a solution to complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

HS-LS2.1: Interdependent Relationships in Ecosystems.  Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. (HS-LS2- a),(HS-LS2-b)

HS-LS2.3: Ecosystem Dynamics, Functioning, and Resilience. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. (HS-LS2-i),(HS-LS2-b)

Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species. (HS-LS2-j)

HS-LS4.4: Biodiversity and Humans. Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). Biological extinction, being irreversible, is a critical factor in reducing the planet’s natural capital. (secondary to HS-LS2-j)

Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. These problems have the potential to cause a major wave of biological extinctions—as many species or populations of a given species, unable to survive in changed environments, die out—and the effects may be harmful to humans and other living things. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. (secondary to HS-LS2-l),(secondary to HS-LS2-j)

HS-ETS1.2: Developing Possible Solutions. When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts. (secondary to HS-LS2-j)

1. **Time/schedule requirements:**

The entire task could take from 8—15 class periods (45-50 minutes each) spread out over the course of an instructional unit, with the divisions listed below:

* Task Components A, B and C: 3-5 class periods total, depending on whether parts are done outside of class.
* Task Components D, E and F: 3-5 class periods total, depending on whether parts are done outside of class.
* Task Component G: Up to 2-3 class periods, depending on whether parts are done outside of class.
* Task Component H: 2-3 class periods, depending on whether parts are done outside of class.
1. **Materials/resources:**
* It is assumed that students have access to graphing calculators and/or a computer plotting or spreadsheet program that allows students to input data and conduct regressions.
* Access to the Internet or a set of articles for students to use is necessary.
* Suggested resources:
	+ Honey Bees and Colony Collapse Disorder, from U.S. Department of Agriculture Agricultural Research Service with information on CCD: [www.ars.usda.gov/News/docs.htm?docid=15572](http://www.ars.usda.gov/News/docs.htm?docid=15572)
	+ Optional introductory video: [www.youtube.com/watch?v=eB4HdG8he4g](http://www.youtube.com/watch?v=eB4HdG8he4g)
	+ U.S. Historical Population Data: [www.census.gov/popest/data/historical/](http://www.census.gov/popest/data/historical/)
	+ USDA National Agriculture Statistics Service’s reports: <http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1191>
1. **Prior knowledge:**

Students successfully completing this task will need to have studied interdependent relationships, population ecology, and energy transfer in ecosystems and be comfortable with function families and using plotting programs to fit a line or curve to the data.

1. **Connection to curriculum:**

This task is aimed at students who have successfully completed the requirements of a rigorous Algebra I course. This task would be used after students have studied interdependent relationships in ecosystems, population ecology, and energy transfer in ecosystems. The task should be completed after students have had experience with modeling contextual situations using linear equations and, ideally, after students have studied a variety of function families, for each of which they could compare the characteristics in determining the best function for the data presented. Fitting a line or curve to data can be done based on the students’ prior experience with families of functions.

The entire task is intended as a summative assessment, particularly within an integrated math/science course. However, because the plotting required in Task Components A, B and C is used as evidence for the discussion in those task components and the ones that follow, the plotting components could be formative while the remainder of the task components could be summative.

1. **Teacher instructions:**

Task Component A

* Hand out Attachment 1 and refer students to the U.S. data.
* Provide instructions to students, which would guide them to making a graph of the honey bee population in the U.S.
* Discuss possible mathematical functions and equations of those functions
* Check in with groups as they are discussing descriptions and predictions of the data with the following in mind:
	+ For datasets that have a lot of variability, the mathematical function serves as a simplified explanation of how the variables are related, identifying a general trend within “noisy” data. Because of this, it is important to evaluate how well the function actually represents the changes in the data set. Students should consider the fit of their function to the data set, and describe how well their chosen function represents the dataset. Students should describe (1) specific characteristics of the fit of the equation to the data, and (2) limitations or inadequacies of the fit of the equation to the data, using specific examples from the scatter plot as evidence.

Task Component B

* Instruct the students to find patterns within patterns in the data and then write new equations, descriptions, and predictions for the diverse patterns in the data.
* Students should describe how the changes over time in the bee colony numbers, and predictions for the future, changed based on how the dataset was mathematically modeled. Students should describe why they might want to model different portions of the data with different functions, and describe what this might mean for how the bee colony data are interpreted.

Task Component C

* Refer the students back to Attachment 1, the California and South Dakota data.
* Instruct students to make a scatterplot graph of California and South Dakota data, choose mathematical functions that models change in bee population, and compare and contrast all three graphs made (US, California, South Dakota.
* Students should answer the following questions:
	+ Can the smaller scale of state data be used to understand/make predictions about the larger scale model for the United States?
	+ Which state would you chose to use if you wanted to conduct a smaller scale experiment on bee colonies that could be used as a way to test solutions for the changes affecting bee colony numbers in the entire U.S.?
	+ Are there any additional factors you would need to consider? Describe the reasoning behind your answer.

Task Component D

* Hand out Attachments 2 and 3.
* Discuss limiting factors, independent and dependent population changes.
* Guide students to apply limiting factors and independent and dependent population factors causing population change to the bee populations.
* Students will also answer the following questions:
	+ Based on the functions that you defined in Task Components A and B, at what point do you think these factors affecting the bee population changed. Describe the reasoning behind your choices. Cite the U.S. or state bee colony numbers, plots, functions, and/or equations as evidence as appropriate.
	+ Also, consider and describe the pressures and influences of larger-scale ecosystems that honey bees are a part of and/or interact with, including the human ecosystem. See Attachments 2 and 3 for a chart and scatter plots of human population data for the U.S., California, and South Dakota to reference when you are constructing your answer.

Task Component E

* Have computer/internet access available.
* Guide students to find USDA-Agricultural Research Services “Honey Bees and Colony Collapse Disorder” webpage.
* Students will review the suspected causes of colony collapse disorder using the above resource or any other external references they may find helpful.
* Students should consider the evidence that connects each suspected cause to CCD and any information on when these cause agents may have become an issue or problem, such as when an invasive species may have been introduced.
* Based on their research and the data and plots produced in previous task components, students should revise their discussion for (a) what factors they think limited the bee populations and determined or defined the carrying capacity of the bee population, keeping it stable, and (b) what factors they think caused the drastic change in the bee populations.
* Based on the functions students defined in Task Components A and B and the data plots, students should evaluate at what point they think these factors affecting the bee populations changed, and how does this timing relate to what is known about the timing of the suspected cause agents?

Task Component F

Students should reconsider their comparison of the U.S., California, and South Dakota bee colony number datasets as follows:

* Based on what they have learned about the suspected causes of CCD and through the evaluation of the U.S. bee colony numbers dataset, they can revise their explanation for how the smaller scales of state data can be used to understand/make predictions about the larger scale model for the United States.
* Include in their revision a description of what they think the data suggests about whether each of the smaller-scale state bee ecosystems are affected by the same causes/stressors as is the larger U.S. bee ecosystem.

Task Component G

* Have computers/internet available.
* Students will construct an argument of how continued trends related to changes in bee colony numbers might be impacting the stability and biodiversity of ecosystems in which the bees participate.
* Students will describe effects on ecosystems outside of the human agricultural system as well as effects on the human ecosystem, specifically related to food production. Clearly state the boundaries and scale of the human and non-human ecosystems that you are describing.
* Students should cite their data plots, functions, and equations as evidence describe why they can be used as evidence.
* Students may also review and cite scientifically relevant external references and examples as evidence.

Task Component H

* Have computers/internet available.
* Based on external research, students will construct a list of suggested solutions for CCD. In the list, students will include solutions that require or use new forms of technology as well as those that are associated with changes in beekeeping practices.
* Students will choose one of these solutions and evaluate the solution using their understanding of population changes and ecosystem stability and any evidence or data uncovered in research of the solution.
* Students will describe how this solution is intended to work to decrease the effects of CCD, determine how well the solution meets the criteria and constraints that are listed below, and define trade-offs in instances of competing criteria:
	+ The solution is effective in decreasing the effects of CCD on bee populations
	+ It is low in cost
	+ It isn’t too complex (doesn’t require a large number of different types of changes)
	+ It is safe for beekeepers to use or administer
	+ It has minimal effect on other species in the ecosystems in which the bees participate
	+ It addresses as many suspected causes of CCD as possible
	+ It is reliable through repeated use
	+ It addresses any cultural, social, or aesthetic concerns of the human community in which the solution is being used
	+ If it involves technology, it is an accessible solution for beekeepers with a range of technological knowledge and capabilities
* Students will respond to the prompt: Based on your evaluation, do you feel that the solution is a viable solution for CCD given the constraints? Describe your reasoning.
1. **Student support:**
	* + Extended time
		+ Provide graphic organizers for each step
		+ Additional check-ins with teacher
2. **Extensions or variations:**
	* This assignment should be done in groups to mimic collaboration in the workplace.
	* If the task is done within an Algebra 1 course, students could be limited to using linear and quadratic function models.
3. **Scoring:**

Student work can be scored using the SCALE Scientific Literacy Rubric (Bee Colonies).

*This task was inspired by the 2010 United Nations Environment Programme (UNEP) Emerging Issues report “Global Honey Bee Colony Disorders and Other Threats to Insect Pollinators.” Available at: (http://www.unep.org/dewa/Portals/67/pdf/Global\_Bee\_Colony\_Disorder\_and\_Threats\_insect\_pollinators.pdf)*