Conserving Genetic Diversity

Subject Area(s) Biology
Associated Unit Genetics
Associated Lesson
Activity Title Conserving Genetic Diversity
Header

Grade Level 9 (9-12)

Activity Dependency

Time Required 50 minutes

Group Size 2-4

Expendable Cost per Group US $0

Summary
A rare species is dying out and students only have enough funds to transport a limited number of the remaining species to conserve. Students must use information regarding allelic differences between species to decide which organisms should be conserved.

Engineering Connection
Conservation biology is a crisis discipline that is tasked with solving the problems inherent in humans continually changing Earth’s landscape. One such concern is not just the amount of a species left on Earth, but the quality of its genetic diversity as well. Here, students devise a plan to conserve optimal species to conserve genetic diversity.

Engineering Category = 1
Choose the category that best describes this activity’s amount/depth of engineering content:
1. Relating science and/or math concept(s) to engineering
2. Engineering analysis or partial design
3. Engineering design process
Keywords
Conservation, Extinction, Gene, Allele, Genetics, Diversity, Evolution, DNA

Educational Standards (List 2-4)
Source, year, standard number(s)/letter(s), grade band and text (its unique ID# is optional)

State STEM Standards (required)
HS-LS3-3. Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.

HS-LS4-6. Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.

HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS-ETS1-3. Evaluate a solution to a 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.

ITEEA Standards (required)
11-O. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.

11-P. Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.

11-Q. Develop and produce a product or system using a design process.

11-R. Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

CCSS Standards (strongly recommended)
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.

RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
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.

WHST.9-12.5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience.

WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

MP.2 Reason abstractly and quantitatively.

Pre-Requisite Knowledge
A basic understanding of how genotypes affects phenotypes with all the requisite knowledge that accompanies it. Additionally, knowledge of basic dominant-recessive patterns, codominance, and incomplete dominance should be understood by students. This activity was designed to occur near the end of a genetics unit as an application of a molecular topic to a macroscopic problem like conservation.

Learning Objectives
After this activity, students should be able to:
  ● Define genetic diversity.
  ● Explain the importance of conserving genetic diversity.
  ● Evaluate and rank populations based on genetic diversity.
  ● Make conservation decisions based on given data.

Materials List
Each group needs:
  ● Conservation Genetics Worksheet
  ● Science Notebooks (Questions can be turned into a full worksheet).

Introduction / Motivation
No two organisms typically look alike. Just as there is great genetic diversity readily observable in humans, nearly all sexually reproducing species experience a high level of genetic variation. Therefore, when we talk about conserving endangered species, it becomes necessary to discuss genetic diversity as well. While we may be able to conserve a species, if all of their genetic diversity is lost, then we have diminished the quality and ability of that species to adapt to natural environmental pressures. In short, genetic diversity is required for the longevity of a species in the wild.

For this activity, you will be paired up to deal with a conservation crisis. Five meadows in a rural town are being optioned to be developed into manufacturing plants. These meadows are the only known location of the rare Sun Aster (*Asteraceae asteraceae*). Local butterflies rely on these asters and are important during their migration. Each meadow parcel of land is roughly the same size and contains roughly equal amounts of the flower. However, it is economically important for this city to have these manufacturing plants constructed. As a result, we are only able to save two meadows from development with current funds. It is up to your team to determine which to save based on the differences in the varieties of Sun Asters located there.
### Vocabulary / Definitions

<table>
<thead>
<tr>
<th>Word</th>
<th>Definition</th>
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<tbody>
<tr>
<td>DNA</td>
<td>Macromolecule responsible for the storage and expression of genetic information important for life processes.</td>
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<tr>
<td>Mutation</td>
<td>A change in the nucleotide sequence of DNA.</td>
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<td>Genotype</td>
<td>The genetic sequence of a given gene.</td>
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<tr>
<td>Phenotype</td>
<td>The physical characteristic expressed by a given gene.</td>
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<tr>
<td>Gene</td>
<td>A sequence of DNA that codes for a protein.</td>
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<td>Allele</td>
<td>A variation in a gene that may lead to different phenotypes (e.g. A or a)</td>
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<td>Gene Pool</td>
<td>The sum of available genetic variation in a population.</td>
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<td>Homozygote</td>
<td>An individual with the same allele at a gene locus (e.g. AA or aa)</td>
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<tr>
<td>Heterozygote</td>
<td>An individual with different alleles at a gene locus (e.g. Aa)</td>
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<tr>
<td>Dominant</td>
<td>Allele that is expressed if present in an organism.</td>
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<tr>
<td>Recessive</td>
<td>Allele that is only expressed if the dominant allele is absent.</td>
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<tr>
<td>Incomplete Dominance</td>
<td>Phenotype where an intermediate form of the recessive and dominant alleles are present (e.g. a pink flower resulting from a cross of a red and white flower).</td>
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<tr>
<td>Codominance</td>
<td>Phenotype where two different alleles are expressed (A red and white flower resulting from a red parent and white parent).</td>
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<tr>
<td>Conservation</td>
<td>Management of biodiversity; here specifically referring to genetic conservation.</td>
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### Procedure

#### Background
A majority of the traits we can see (or even can’t see) are coded by different genes within an organism’s DNA. These genes may come in different variations called alleles (e.g. a gene coding for fur color may have three different alleles, such as orange, white, or black fur). These alleles are often at odds with one another such that one allele, a dominant allele (notated with a capital letter such as A), will always be expressed whereas recessive alleles (notated with lower-case letters such as a) are expressed only when there is no competition from a dominant allele. However, heterozygous individuals (those with a dominant and recessive allele) may express both alleles in a codominant expression or an intermediate between the two alleles in an incomplete dominance expression.

#### Before the Activity
- Make copies of the Conservation Genetics Worksheet so that each group has a copy.

#### With the Students
1. Introduce the topic of conservation genetics to students and review relevant genetics vocabulary.
2. Divide students up into groups of 2-4.
3. Pass out the Conservation Genetics Worksheet to each team.
4. Have students work through each question in the worksheet; monitor their progress throughout the activity keeping track of the time.
5. With the last 5-10 minutes of class, hold a class-wide discussion of the ideal two meadows to protect and the reasoning behind it.
Attachments
Conservation_Genetics_Worksheet.pdf

Safety Issues
No expected safety issues; standard classroom protocol would be sufficient.

Troubleshooting Tips
Allow students to develop their own methods of quantifying data; an important skill of science is not just data collecting, but knowing how to quantify data you collect.

Investigating Questions
None

Assessment

Pre-Activity Assessment
Journal Writing: Students write in their science notebooks their thoughts on the following prompt:
1. What biological advantage is there to having physical diversity among members of the same species? OR what negative consequences are there to having a population of genetically identical species?

Activity Embedded Assessment
Brainstorming: After presenting the problem, have students brainstorm how they could quantify the genetic diversity between each population (questions 1-5 on worksheet)
Management Plan: Students extract data from their given environments and develop a logical argument for the conservation of one site over another when resources are limited (question 6 on worksheet).

Post-Activity Assessment
Debate: After all student pairs complete their own management plans, pairs share their decisions and create a consensus on a conservation plan.

Activity Extensions
One method of quantifying genetic diversity is to use fixation indexes of these populations by calculating the frequencies of each allele. The wikipedia page on F-statistics is sufficient to understand how one may go about finding these values. These calculations would also fit in a lesson while talking about Hardy-Weinberg equilibrium in an AP Bio course.

Activity Scaling
● For lower grades, the teacher may provide the genotypes instead of the phenotypes in the worksheet (red = AA, pink = Aa, and white = aa).
● For higher grades, see activity extensions.

Additional Multimedia Support
None

References
1. Info on Conservation Genetics
2. Adapted from Problem-Solving in Conservation Biology and Wildlife Management and designed for a younger audience.
Contributors
This activity was prepared by Wil Falkner with the guidance and critiques from the Research Experience for Teachers (RET) 2019 group at Central Michigan University.

Supporting Program
This lesson plan was drafted as part of the RET program, funded by the National Science Foundation and hosted at Central Michigan University.

Acknowledgements
Special thanks to Dr. Kumar Yelamarthi and Julie Cunningham, PI and co-PI for the RET program. Thanks also to Beth Christiansen for her instruction and guidance on designing lesson plans to align with Next Generation Science Standards.

Classroom Testing Information
N/A
Conservationist Information

You and your team are conservationists attempting to save a rare species of aster, the Sun Aster (Asteraceae asteraceae). Here are the observations and problems you have identified already:

The Problem: A manufacturing company is looking to purchase unused meadows to develop into a new manufacturing plant. There are currently five meadow lots available for sale, but your conservation group has the funds to save two of these meadows from development, but only if you act fast enough! It is up to your group to decide which meadows should be saved.

The Meadows: Each of the five plots of land are of equivalent size, price, and population of Sun Asters. Therefore, any two meadows will conserve the same amount of asters, but this does not mean each meadow is of the same quality in terms of the genetic diversity of the asters. Each field was surveyed by other conservationists, but due to the immediacy of your actions, only fifteen specimen were taken from each field and their color is specified below:

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<thead>
<tr>
<th>Field 1</th>
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<th>Field 5</th>
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<td>Red, Pink, Pink, Red, Red, Pink, Pink, Red, Red, Pink, Red, Pink, White, Red</td>
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With your group, answer the following questions in your science journals and be prepared to share with the class:

1. What type of expression is shown with these asters (complete dominance, codominance, or incomplete dominance)? What is your evidence?

2. Based on your answer to #1, can you infer which flower color is the heterozygous individual? Can you tell which color is dominant or recessive?

3. For question #2, if we are only looking for genetic diversity, does it matter which colors are dominant and recessive or do we only have to know that they are different alleles?

4. Evaluate the genetic diversity of each of the five fields; how you determine this information is up to your group. Decide as a group how you want to quantify your results. In your journal, write your process as well as a final table describing each meadow.

5. Individually, rank the meadows in terms of desirability to conserve. Explain how you came to your decision.

6. As a group, discuss which two meadows you would recommend your conservation group to purchase. Use evidence to explain your conservation plan.

7. Challenge Problem: If time, discuss the purpose of examining genetic diversity when all meadows contain all of the alleles. Why does it matter what the genetic diversity experienced in the population is when each meadow has a sufficiently large population?