Title: Symbiosis in Stress: Effects of Climate Change on Biomes & Symbiotic Relationships

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Abstract:
Biomes, ecosystems, and interspecific interactions are all key components to understanding ecology. Tragically, climate change is greatly impacting each of these three. In this lesson, students will utilize maps and models to determine the implications of continued climate change. From their investigations of current climate trends, they will predict the impact on interspecific interactions and present their findings to the class.

Subject, Grade, Level:

Grades: 9-12
Standard/Honors Biology AICE Biology
AP Biology IB Biology

Learning Objectives:
Students will be able to...
- Predict the impacts of climate change on terrestrial biomes and their constituent species.
- Interpret maps and models to determine climate and ecological trends.
- Describe illustrative examples of interspecific interactions, including mutualism, commensalism, parasitism, amensalism, and competition.

Timeframe:
Advanced Preparation: Approximately 15 minutes is necessary in order to become familiar with the data provided by the maps and each of the species interactions. An additional 10 minutes is required for printing and laminating all materials for multiple uses.
Lesson: The lesson could be completed within a 50-minute class period, or if necessary, extended to a second day (15-20 minutes) for overnight research and refinement of presentations.

List of materials:
- Laminated map models (See appendix) - 1 set per 2 to 4 students
- Laminated species identifiers – 1 set per class
- Computers or tablets – 1 per every 2 students
- Post-it® Wall Pad sheets – 1 per every 2 students

INSTRUCTOR: Procedure and General Instructions

Advanced Preparation
Print the maps in as large of a file as possible with the greatest resolution and laminate them for future use. The maps MUST be printed in color. Provide a set of each of the map models to
the students and have them arranged in groups of 2 to 4. Provide a printed copy or post the accompanying questions on an overhead projector.

On index cards, print the images and names of the two species on one side of the card (common name can suffice, but scientific name is always more helpful for research purposes). On the back of the index card, include the accompanying questions. Divide the students into pairs, hand them an interspecific interaction index card and also one large wall Post-it® sheet for a gallery walk.

*Map and Model Analysis*

In a whole group setting, preface that the Earth is divided into two biome types: terrestrial and aquatic. For terrestrial biomes, there are 8 major classes:

1. Tundra
2. Desert
3. Tropical forests (rainforests and dry forests)
4. Temperate forests
5. Temperate grasslands
6. Coniferous forests (taiga)
7. Savanna
8. Chaparral

Address the students about climate change and there is global warming in some locations, but also the impacts of change in seawater temperature leading to differing winds, storm strength, and temperatures.

- **Warmed Locations:** Canada, South Africa, Asia, Antarctica
- **Cooled Locations:** Southeastern United States, Andes Mountains, Madagascar
- **Variable Weather Patterns:** Uncharacteristic snows in the Northeast, Sahara Desert, Italy, and Greece, stronger hurricanes, increased precipitation and heavier rains in the U.S., and longer periods of drought (South Africa and the southwest U.S.)

Divide the class into groups of 2-4 students and inform them that they will be using map models to identify how scientists predict biomes and their accompanying climates will change with increased mean global temperatures.

Students should discuss and take notes on the following questions:

- What changes are evident from the data?
- What remains unchanged despite the change in global temperature means?
- How is ice and permafrost impacted in particular? (Use this as an opportunity to discuss with the whole class how the conversion of water from solid to liquid state will increase volume and how melting of the permafrost exposes carbon sinks that increases CO2 levels which leads to a positive feedback loop for climate change).
Once adequately discussed, students should be directed to use a computer, tablet, or personal device to look up predicted global sea level changes, especially in the U.S. and the Southeast (especially Florida!).

- Which states are most affected? Which cities?
- How many people do you predict would be affected? (Encourage students to actually look up population data rather than random guesses)
- Where will the people go?
- What kind of economic or society impact will that cause?

**Interspecific Interactions**

Transition students from impacts on humans to impact on life on Earth as a whole. Probe the class to see if they can identify forms of interspecific interactions: (There is a debate on how many there are, some texts identify three major ones due to their longevity of interactions [the first 3 below], while others include many more regardless of longevity. In this case, a hybrid set of 5 is used and a 6th/7th is in parentheses below).

1. Mutualism (+/+)
2. Commensalism (+/0)
3. Parasitism (+/-)
4. Competition (-/-)
5. Amensalism (0/-)
6. (Predation/Herbivory) (+/-)

Discuss the +/- species interactions for all that are listed (see above for answers – withhold these from the class until the discussion). Inform students that they will be given a set of two species that interact in one of the aforementioned ways. They are to research their species and determine the following:

- What kind of interaction are the two species exhibiting?
- Which biome do the species primarily reside?
- How will climate change affect each species and how might it impact their relationship?
- What are the downstream effects of climate change on their relationship? Examples include impact on the food chain, other interspecific interactions, distribution, fitness for other environments, etc.

Students will then record their information on a wall-size Post-it® note and will engage in a gallery walk. One student of the pair can stay and present, while the other listens to the other presentations. Students should take no longer than 2 minutes to present their interaction. Given the number of species cards, the teacher can elect to have the students create their presentation at home and present it in its entirety the next day. Another potential modification is having the students listen to one example of each of the five interactions. Speakers and listeners should alternate roles at some point during the gallery walk.
Reference list

Supplemental Reading
Appendix A: Model Agreement on Climate Change-Driven Biome Shift Between 1990 and 2100

Appendix B: Locations of Observed Biome Shifts During the 20th Century

Appendix C: Distribution of Terrestrial Biomes

Appendix D: Biome Shifts Detected in the U.S. and Attributed to Climate Change


RE: Tropical Evergreen Broadleaf Forest
RB: Tropical Deciduous Broadleaf Forest
RW: Tropical Woodland
RG: Tropical Grassland
DE: Desert
TG: Temperate Grassland
TS: Temperate Shrubland
TM: Temperate Mixed Forest
TB: Temperate Broadleaf Forest
TC: Temperate Coniferous Forest
BC: Boreal Forest
UA: Tundra & Alpine
Appendix E: Interspecific Interactions Index Cards

TEMPERATE FOREST: PARASITISM

- Eastern Moose
  *Alces alces*
- Winter Tick
  *Dermacentor albipictus*

TROPICAL FOREST: PARASITISM

- “Zombie” Fungus
  *Ophiocordyceps unilateralis*
- Carpenter Ant
  *Camponotus rufipes*

DESERT: PARASITISM

- Coyote
  *Canis latrans*
- Dog Flea
  *Ctenocephalides canis*

TUNDRA: MUTALISM

- Arctic Kidney Lichen
  *Nephroma arcticum*
- Green Algae
  *Coccomyxa sp.*
Appendix E: Interspecific Interactions Index Cards

SAVANNA: MUTUALISM
- Red-Billed Oxpecker
  *Buphagus erythrorhynchus*
- Impala
  *Aepyceros melampus*

TEMPERATE GRASSLAND: MUTUALISM
- Monarch Butterfly
  *Danaus plexippus*
- Milkweed
  *Asclepias sp.*

TROPICAL FOREST: PARASITISM
- Corpse Lily
  *Rafflesia arnoldii*
- Grape Vine
  *Tetrastigma rafflesia*

TUNDRA: COMMENSALISM
- Caribou (Reindeer)
  *Rangifer tarandus*
- Arctic Fox
  *Vulpes lagopus*
### Appendix E: Interspecific Interactions Index Cards

<table>
<thead>
<tr>
<th>CHAPARRAL: COMMENSALISM</th>
<th>DESERT: COMMENSALISM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Red-winged Blackbird</strong></td>
<td><strong>Cactus Wren</strong></td>
</tr>
<tr>
<td><em>Agelaius phoeniceus</em></td>
<td><em>Campylorhynchus brunneicappilus</em></td>
</tr>
<tr>
<td><strong>Black Willow</strong></td>
<td><strong>Cholla Cactus</strong></td>
</tr>
<tr>
<td><em>Salix nigra</em></td>
<td><em>Cylindropuntia bigelovii</em></td>
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</tbody>
</table>

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<thead>
<tr>
<th>CONIFEROUS FOREST: AMENSALISM</th>
<th>TEMPERATE FOREST: AMENSALISM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Humans</strong></td>
<td><strong>Black Walnut</strong></td>
</tr>
<tr>
<td><em>Homo sapiens</em></td>
<td><em>Juglans nigra</em></td>
</tr>
<tr>
<td><strong>Sea Oats</strong></td>
<td><strong>Rhododendron</strong></td>
</tr>
<tr>
<td><em>Uniola paniculata</em></td>
<td><em>Rhododendron sp.</em></td>
</tr>
</tbody>
</table>
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SAVANNA: COMPETITION

Lion
*Panthera leo*

Cheetah
*Acinoxyx jubatus*

TEMPERATE FOREST: COMPETITION

Red-bellied Woodpecker
*Melanerpes carolinus*

Eastern Grey Squirrel
*Sciurus carolinensis.*

CHAPARRAL: COMPETITION

Island Grey Fox
*Urocyon littoralis*

Iberian Lynx
*Lynx pardinus*