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

Author(s):
William J. Furiosi II
Oviedo High School
william_furiosi@scps.k12.fl.us

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 in 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

Climate Central. (2016). Seeing choices: Surging seas [Interactive map]. Retrieved from https://choices.climatecentral.org/#12/40.7117/-74.0008

Grimm, N. B., Chapin, F. S., Bierwagen, B., Gonzalez, P., Groffman, P. M., Luo, Y., ... Williamson, C. E. (2013). The impacts of climate change on ecosystem structure and function. *Frontiers in Ecology and the Environment*, *11*(9), 474-482. doi: 10.1890/120272

Settele, J., Scholes, R., Betts, R., Bunn, S., Leadley, P., Nepstad, D., … & Taboada, M.A. (2014) Terrestrial and inland water systems. In C*limate change 2014: Impacts, adaptation, and vulnerability* (pp. 271-359). Cambridge, U.K. & New York, NY, U.S.A.: Cambridge University Press.

Supplemental Reading

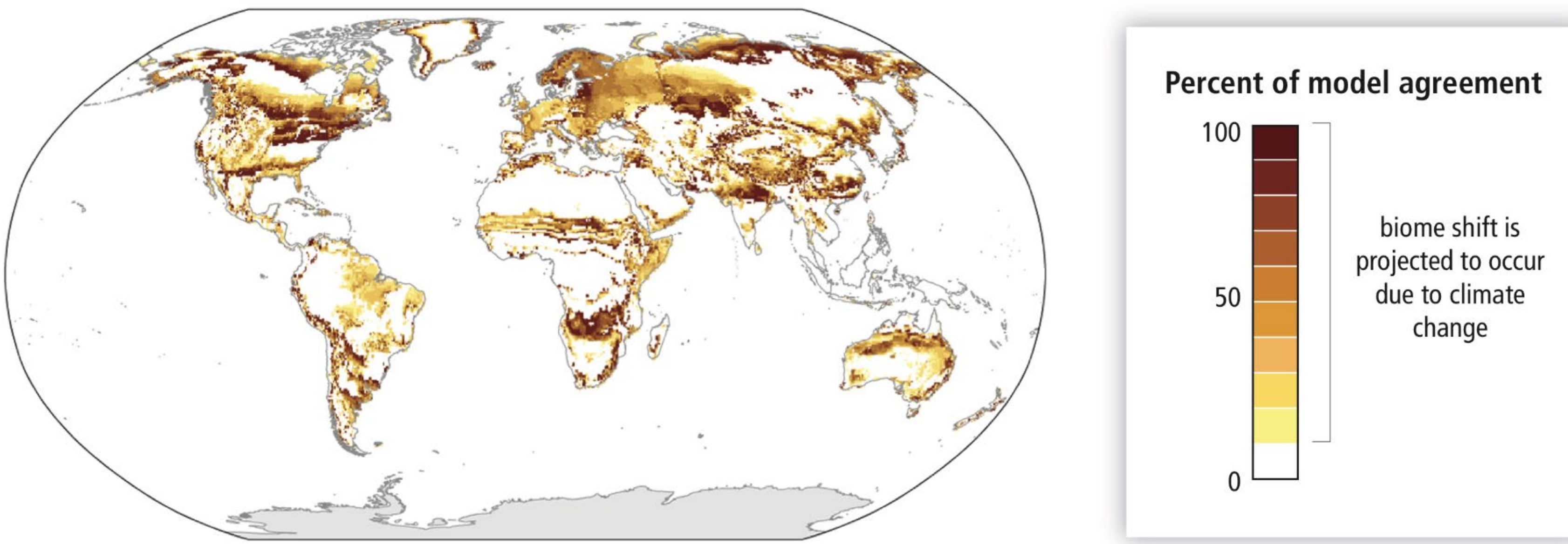
Green, W. (n.d.) Topic 2.4: Biomes, zonation, and succession [Web page]. Retrieved from https://www.mrgscience.com/ess-topic-24-biomes-zonation-and-succession.html

Ji, F., Wu, Z., Huang, J. & Chassignet, E. P. (2014). Evolution of land surface air temperature trend. *Nature Climate Change*, *4*, 462-466. doi: 10.1038/nclimate2223

Mougi, A. (2016). The roles of amensalistic and commensalistic interactions in large ecological network stability. *Scientific Reports*, *6*. doi: 10.1038/srep29929

Staudinger, M. D., Carter, S. L., Cross, M. S., Dubois, N. S., Duffy, J. E., Enquist, C., … & Turner, W. (2013). Biodiversity in a changing climate: A synthesis of current and projected trends in the U.S. *Frontiers in Ecology and the Environment, 11*(9), 465-473. doi: 10.1890/120272

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



Ji, F., Wu, Z., Huang, J. & Chassignet, E. P. (2014). Evolution of land surface air temperature trend. *Nature Climate Change*, *4*, 462-466. doi: 10.1038/nclimate2223

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

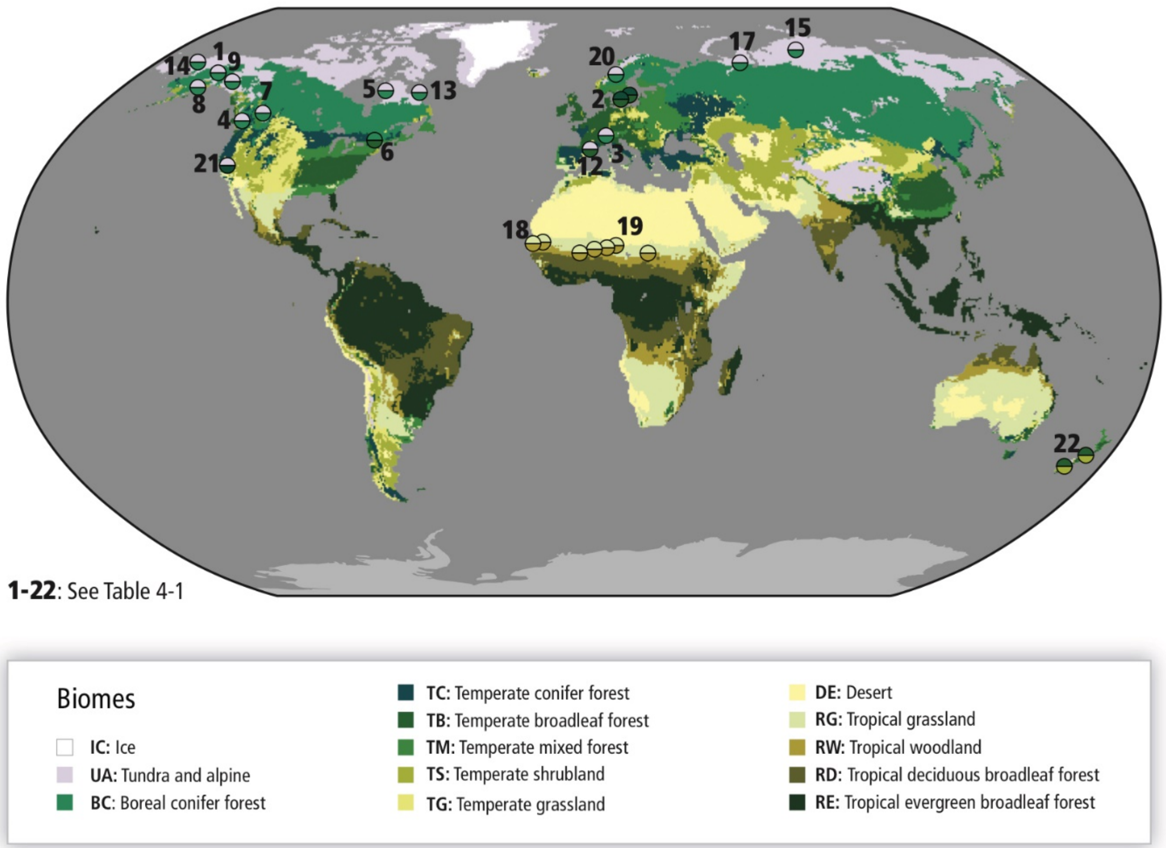
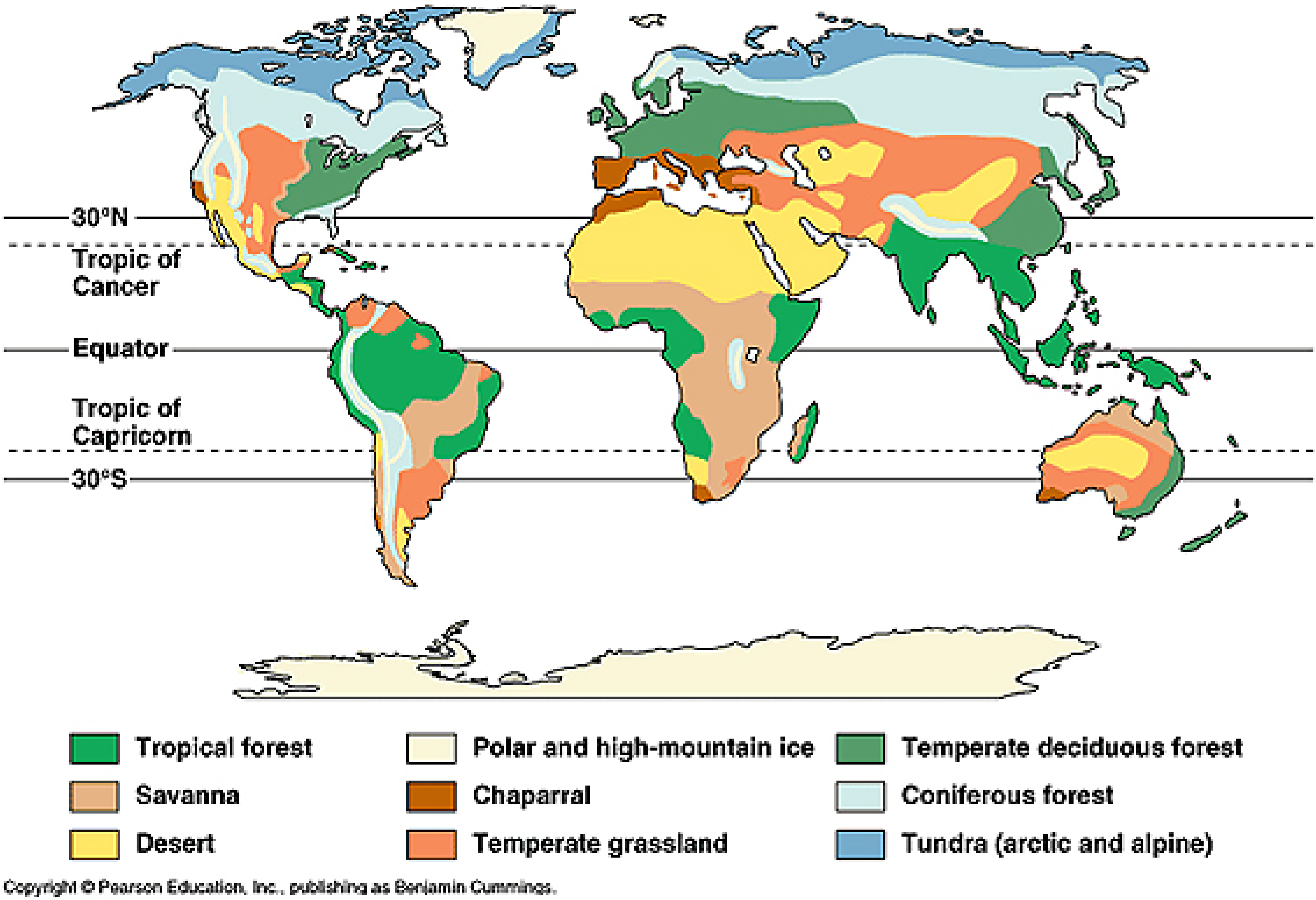


Figure 4-1 | Locations of observed biome shifts during the 20th century, listed in Table 4-1, derived from Gonzalez et al. (2010). The color of each semicircle indicates the retracting biome (top for North America, Europe, Asia; bottom for Africa and New Zealand) and the expanding biome (bottom for North America, Europe, Asia; top for Africa and New Zealand), according to published field observations. Biomes, from poles to equator: ice (IC), tundra and alpine (UA), boreal conifer forest (BC), temperate conifer forest (TC), temperate broadleaf forest (TB), temperate mixed forest (TM), temperate shrubland (TS), temperate grassland (TG), desert (DE), tropical grassland (RG), tropical woodland (RW), tropical deciduous broadleaf forest (RD), tropical evergreen broadleaf forest (RE). The background is the potential biome according to the MC1 dynamic global vegetation model under the 1961–1990 climate. No shift was observed on locations 10, 11, 16, and 23 (see Table 4-1).

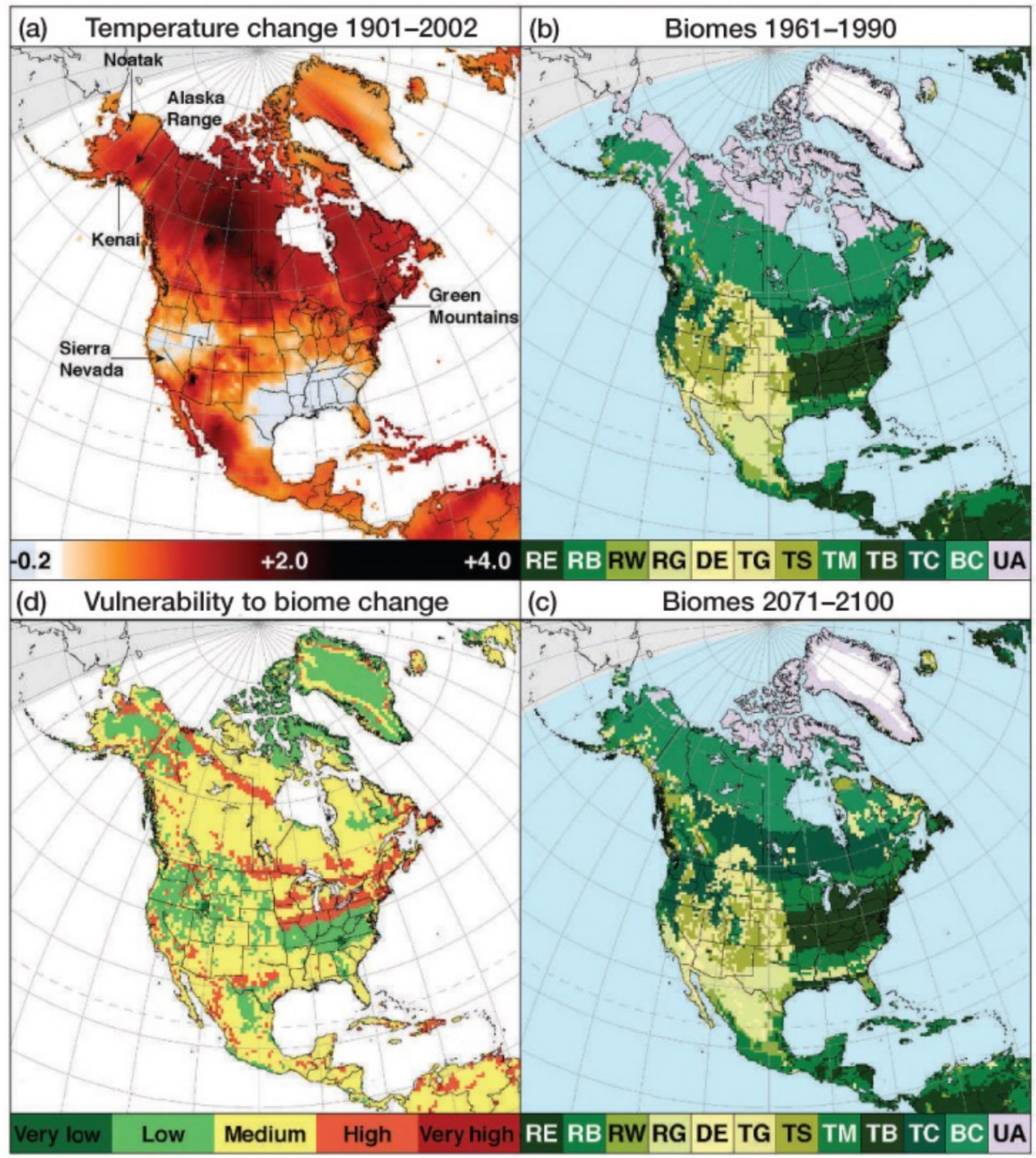
Settele, J., Scholes, R., Betts, R., Bunn, S., Leadley, P., Nepstad, D., … & Taboada, M.A. (2014) Terrestrial and inland water systems. In *Climate change 2014: Impacts, adaptation, and vulnerability* (pp. 271-359). Cambridge, U.K. & New York, NY, U.S.A.: Cambridge University Press.

Appendix C: Distribution of Terrestrial Biomes



Reece, J. B., Urry, L. A., Cain, M. L., Wasserman, S. A., Minorsky, P. V., Jackson, R., & Campbell N.A. (2007). *Campbell biology* (8th. ed.) Boston, MA: Pearson.

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

Grimm, N. B., Chapin, F. S., Bierwagen, B., Gonzalez, P., Groffman, P. M., Luo, Y., ... Williamson, C. E. (2013). The impacts of climate change on ecosystem structure and function. *Frontiers in Ecology and the Environment*, *11*(9), 474-482. doi: 10.1890/120272

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

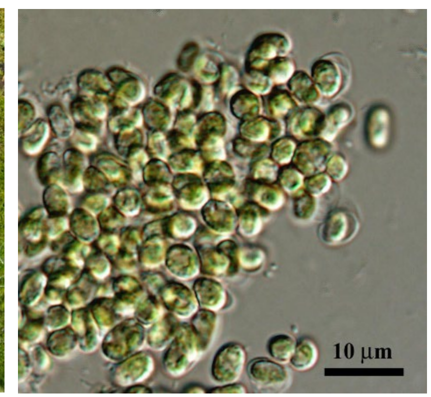
DESERT: PARASITISM

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

CHAPARRAL: COMMENSALISM

Red-winged Blackbird
Agelaius phoeniceus

Black Willow
Salix nigra

DESERT: COMMENSALISM

Cactus Wren
Campylorhynchus brunneicappilus

Cholla Cactus
Cylindropuntia bigelovii.

CONIFEROUS FOREST: AMENSALISM

Humans
Homo sapiens

Sea Oats
Uniola paniculata

TEMPERATE FOREST: AMENSALISM

Black Walnut
Juglans nigra

Rhododendron
Rhododendron sp.

Appendix E: Interspecific Interactions Index Cards

SAVANNA: COMPETITION

Lion
Panthera leo

Cheetah
Acinoyx 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