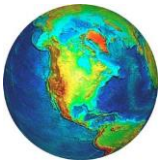


Visualizing changes in the Earth System: Climate Change and Invasive Species— More or Less

Overview: When people think about the future they form a mental image of what it may be like. They use their imagination along with knowledge they have about themselves and others, as well as events they've experienced to build a new scenario of what they can expect.

As we consider the impacts of climate change on the Great Lakes, there are a number of ways of visualizing those changes.

Objectives: At the conclusion of the lesson, students will be able to:

- Provide examples of potential impacts caused by climate change
- Discuss various interpretations of the role that climate change can play in the establishment and spread of invasive species in the Great Lakes
- Recognize some common native and invasive species in the Great Lakes

Duration: This lesson can be completed in one class period if the activity is played once. Ideally it should be played multiple times so students can observe different outcomes depending on students knowledge, the cards used and their distribution.

Standards:

- Share ideas about science through purposeful conversation
- Communicate and present findings of observations
- Identify the impact of climate change on native and invasive species
- Describe helpful or harmful effects of humans on the environment (climate change, habitat destruction, land management, renewable, and non-renewable resources)
- Predict how changes in climate might affect species survival and distribution
- Describe how humans are part of the Earth's system and how human activity can purposefully, or accidentally, alter the balance in ecosystems

Prerequisite Teacher Knowledge:

Aquatic invasive species (AIS) are species that are found outside of their native habitat and cause harm to their new environment. They are highly competitive and persistent. There are over 185 non-native species in the Great Lakes, and the trend has been one new species every 6-8 months. As the climate continues to warm, and the Great Lakes experience additional stressors, AIS may become an even bigger problem as warming temperatures, changing water quality, and disturbance may allow new AIS to expand their ranges and make their home in the Great Lakes. This illustrates the need to be vigilant and step-up efforts to prevent AIS introductions. Most of those responsible for

fighting AIS infestations realize that it is less expensive to prevent their introduction in the first place than to try to control or eradicate them once an infestation has occurred.

To prevent future invasions it would be helpful to know the answers to a few questions: Are there characteristics that are common between different invasive species? How can we tell which habitats are most at risk?

Aquatic invasive species have certain characteristics that tend to make them successful:

- Rapid growth and reproduction: tend to grow quickly and produce a lot of offspring; many reproduce multiple times in one season.
- Asexual reproduction: some species need only one individual to reproduce; especially plants, which may need only a small plant fragment to start a completely new population.
- Adaptability: typically hardy and able to tolerate a wide range of environmental conditions, including degraded and polluted habitats and rapidly changing conditions that native species can't tolerate.
- No predators: Since these species are non-native, they often lack the natural predators that would keep their population numbers in check.

Global climate change may make conditions more suitable for invasive species.

Warming temperatures, increased precipitation, and other climate change impacts predicted by scientists presents a whole new challenge to invasive species management. While it is unknown exactly how AIS may respond to a changing climate, it is predicted that many species will benefit from these changes, expand their ranges, and have exacerbated negative impacts. Due to the characteristics that allow AIS to become successful, these species will most likely have the upper hand at trying to adapt to changing conditions, which may allow them to further outcompete existing native species.

Materials and Preparation

- Blank wall, chalkboard, or bulletin board
- 1 card labeled CLIMATE CHANGE (white or red)
- 20 cards labeled MORE (light color, such as yellow)
- 20 cards labeled LESS (same color as More cards)
- 35–40 impact cards that could result from climate change (contrasting light color, such as green)

Gather or construct the materials listed. Before beginning the activity, create impact cards (factors or activities which could be affected by climate change). These impact

cards should include both scientific impacts and social impacts (focus on things that can go up and down).

MAKE CARDS FOR POSSIBLE CLIMATE CHANGE EFFECTS

"MORE OR LESS" of THESE FACTORS

evaporation	income	crop production
snow	extinction	cooperation
drinking water	lake levels	warm water fish
severe storms	lakefront property	wetlands
insect pests	rain	tourism
recreation	toxic air pollution	forests
water pollution	electricity	drought
flooding	fear	debate
Biological diversity	shipping	summer
winter	disease	air conditioning
ducks	soil moisture	weeds
fertilizer use	pesticide use	dredging
invasive fish	invasive plants	invasive invertebrates
invasive reptiles	invasive pathogens	cold-water fish
shoreline development	people	water diversion
algal blooms		

Introduction:

Ask the students about their prior knowledge about climate change and invasive species.

- Can they name any invasive species? Do they know the issues caused by those species or what people are doing to control them?
- Ask students how they think a changing climate might impact these species? What changes are expected? What kind of species will do better after these changes? What kinds of species might do worse?

Tell students that they will now participate in an activity to learn about the impacts of climate change on the environment and invasive species in particular.

Activity:

1. Tape CLIMATE CHANGE CARD in the center of a blank wall.

2. Stack **MORE** cards and **LESS** cards in two piles and spread the impact cards out over a large table so students can see most of the cards at one time.

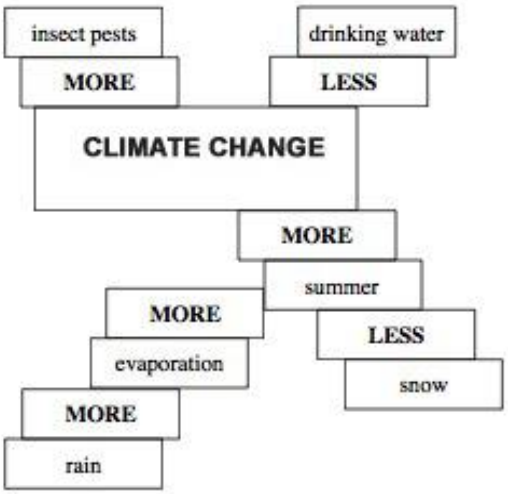
3. If used as a pretest, tell students only that climate change is likely to result in lower water levels and changes in the seasons.

{As a post test, this step needs no introductions.}

Invite students to come forward one table or row at a time and select an impact card, which they feel is the direct result of a previously mounted card. They should then select either a **MORE** or a **LESS** card (whichever they think to be correct for that impact). For example, the first student may decide that GLOBAL WARMING (taped to the wall) leads to MORE INSECT PESTS, or LESS DRINKING WATER. Students must be able to justify the position of the cards they add, and their choice of **MORE** or **LESS** impact.

4. As students use these cards, it will become apparent that there are various interpretations to the impacts. For instance, more weeds and insect pests would probably invade the region, and soil moisture would probably decrease if global warming occurred. However, annual temperatures would be higher and growing seasons longer. The net result could be either more or less crop production. Much would depend on the fertility of northern soils; where and when precipitation fails; and which crops are grown. Have the class discuss all interpretations.

See example below:



5. To assess student understanding, it may be helpful to have each student select a chain of at least eight cards, diagram them in a portfolio, and give a possible explanation for the links.

6. Repeat the activity after students gain more knowledge about climate change and invasive species. Point out to students how the outcomes differ between rounds. What caused the outcome to change? (See Extensions and Alternatives for before and after unit ideas.)

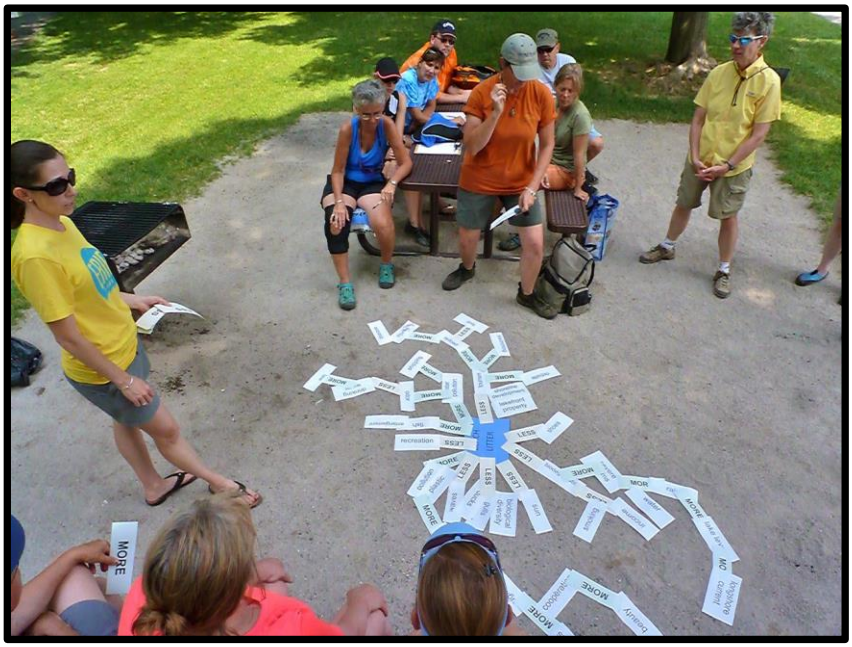
Review Questions

1. List and discuss potential scientific and social factors which may be affected by climate change.

2. Those who deny climate change insist that climate scientists prove beyond any reasonable doubt that climate change poses an imminent danger before we take action as a society. Who should policy makers believe and why and how should they deal with such dilemmas?

Extensions and Alternatives

This activity can also be used at various stages of a unit. For instance, it can introduce a new topic and relate it to previous ones or it can be a culminating activity to draw all aspects of a study together. In addition, it would be an interesting evaluation to take a picture of the concept map created at the beginning of a unit and compare it with the map produced at the end. Some teachers use this as a group activity among 4-6 students. Instead of sheets of paper, they use 3x5 cards. This avoids the problem of students having to wait for their turn at the board, and it also results in many different maps that can be compared in group discussions. Groups can prepare a written or oral presentation of their maps, analyzing the thinking about interrelationships that produced the array.



Answers to Review Questions

1. Accept a large variety of answers for this question. Jobs would be created to help develop new crop seeds that could tolerate warmer, dryer conditions. Farmers would need to adjust their crops and farming practices to respond to the changing conditions. Recreation facilities would need to change their structure for the longer summer season, lowered water levels, and warmer temperatures. Anglers and manufacturers of fishing gear would need to be flexible because spawning grounds for fish would decrease and new species would become abundant. Companies that use toxic chemicals may need to adjust their procedures because increased temperatures and incidence of severe storm would cause airborne pollutants to travel further. The lowered lake and river levels would also greatly impact the shipping industry because boats would either be unable to pass through certain areas or would be required to carry a lighter load. This would have repercussions on the companies that use this method to transport goods.

Most scientists believe that invasive species (plants, fish and other animals) would increase due to a wider range of temperatures in the Great Lakes. This would allow for range expansion and changes in habitats, that would be more suitable for invading species. Many species that may be limited due to colder water temperatures would be able to survive in the new warmer water temperatures. Invasive plants ordinarily found in southern areas could move up to the Great Lakes region. Also, the growing season would be extended, so invasive plants would have a better chance to grow and propagate. The increased rainfall or, conversely, droughts that could occur with climate change may also shift the ranges of invasive species and provide new opportunities for invasion.

2**.** Insisting that climate scientists prove beyond any reasonable doubt that climate change poses an imminent danger before we take action as a society is like saying we shouldn't buy car insurance unless there is absolute proof that we will be involved in an accident. There are uncertainties in climate projections, and possible outcomes range from benign to catastrophic, but doing nothing puts all life at unnecessary risk.

Scientific societies and scientists have released statements and studies showing the growing consensus on climate change science. A common objection to taking action to reduce our heat-trapping emissions has been uncertainty within the scientific community on whether or not global warming is happening or if humans cause it. However, there is now an overwhelming scientific consensus that global warming is indeed happening and humans are contributing to it.

Our understanding of the particulars of climate change continues to evolve, and predictions of specific impacts may be revised upward or downward. However, the majority (97%) of climate scientists who specialize in understanding the complex interactions of our atmosphere, Earth, and Sun have concluded that:

"There is unequivocal evidence that Earth's lower atmosphere, ocean, and land surface are warming; sea level is rising; and snow cover, mountain glaciers, and Arctic sea ice are shrinking. The dominant cause of the warming since the 1950s is human activities.

This scientific finding is based on a large and persuasive body of research. The observed warming will be irreversible for many years into the future, and even larger temperature increases will occur as greenhouse gases continue to accumulate in the atmosphere. Avoiding this future warming will require a large and rapid reduction in global greenhouse gas emissions. The ongoing warming will increase risks and stresses to human societies, economies, ecosystems, and wildlife through the 21st century and beyond, making it imperative that society respond to a changing climate. To inform decisions on adaptation and mitigation, it is critical that we improve our understanding of the global climate system and our ability to project future climate through continued and improved monitoring and research. This is especially true for smaller (seasonal and regional) scales and weather and climate extremes, and for important hydroclimatic variables such as precipitation and water availability.

Technological, economic, and policy choices in the near future will determine the extent of future impacts of climate change. Science-based decisions are seldom made in a context of absolute certainty. National and international policy discussions should include consideration of the best ways to both adapt to and mitigate climate change. Mitigation will reduce the amount of future climate change and the risk of impacts that are potentially large and dangerous. At the same time, some continued climate change is inevitable, and policy responses should include adaptation to climate change. Prudence dictates extreme care in accounting for our relationship with the only planet known to be capable of sustaining human life."
[This statement is considered in force until August 2017 unless superseded by a new statement issued by the American Meteorological Society Council before this date.]

To most of us, uncertainty means not knowing. To scientists, however, uncertainty is how well something is known. And, therein lies an important difference, especially when trying to understand what is known about climate change. In science, there's often not absolute certainty. But, research reduces uncertainty. In many cases, theories have been tested and analyzed and examined so thoroughly that their chance of being wrong is infinitesimal. Other times, uncertainties linger despite lengthy research. In those cases, scientists make it their job to explain how well something is known. When gaps in knowledge exist, scientists qualify the evidence to ensure others don't form conclusions that go beyond what is known.
Even though it may seem counterintuitive, scientists like to point out the level of uncertainty. Why? Because they want to be as transparent as possible and it shows how well certain phenomena are understood.

Decision makers in our society use scientific input all the time. But they could make a critically wrong choice if the unknowns aren't taken into account. For instance, city planners could build a levee too low or not evacuate enough coastal communities along an expected landfall zone of a hurricane if uncertainty is understated. For these reasons, uncertainty plays a key role in informing public policy.

Taking into account the many sources of scientific understanding, climate scientists have sought to provide decision-makers with careful language regarding uncertainty. A

"very likely" outcome, for example, is one that has a greater than 90 percent chance of occurring. Climate data or model projections in which we have "very high confidence" have at least a 9 out of 10 chance of being correct.

However, in this culture of transparency where climate scientists describe degrees of certainty and confidence in their findings, climate change deniers have linked less than complete certainty with not knowing anything. The truth is, scientists know a great deal about climate change. We have learned, for example, that the burning of fossil fuels and the clearing of forests release carbon dioxide (CO2) into the atmosphere. There is no uncertainty about this. We have learned that carbon dioxide and other greenhouse gases in the atmosphere trap heat through the greenhouse effect. Again, there is no uncertainty about this.

Earth is warming because these gasses are being released faster than natural processes can absorb them. It is very likely (greater than 90 percent probability) that human activities are the main reason for the world's temperature increase in the past 50 years.

Scientists know with very high confidence, or even greater certainty, that:

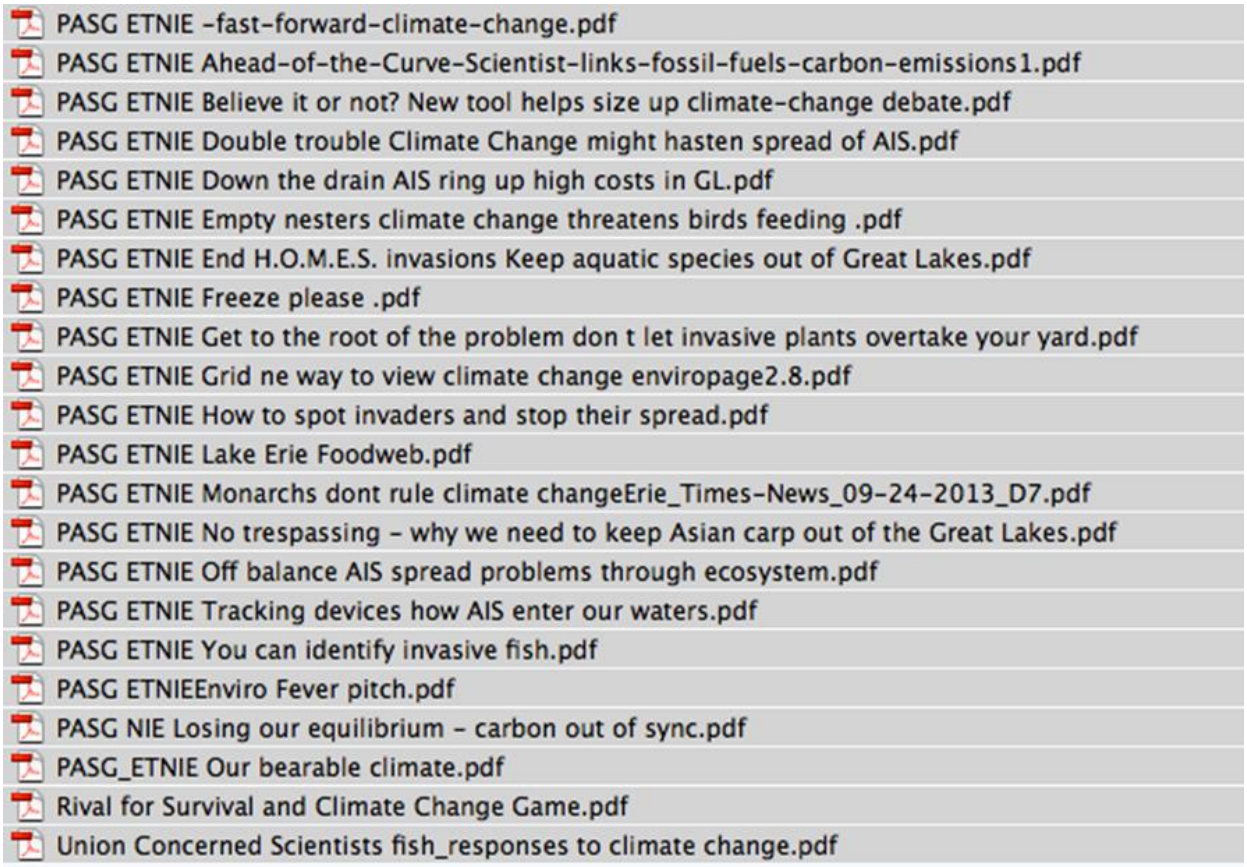
- Human-induced warming influences physical and biological systems throughout the world
- Sea levels are rising
- Glaciers and permafrost are shrinking
- Oceans are becoming more acidic
- Ranges of plants and animals are shifting

Scientists are uncertain, however, about how much global warming will occur in the future (between 2.1 degrees and 11 degrees Fahrenheit by 2100). They are also uncertain how soon the summer sea ice habitat where the ringed seal lives will disappear. Curiously, much of this uncertainty has to do with—are you ready?—humans. The choices we make in the next decade, or so, to reduce emissions of heat-trapping gasses could prevent catastrophic climate change.

So, what's the bottom line? Science has learned much about climate change. It tells us what is more or less likely to be true. We know that acting now to deeply reduce heat-trapping emissions will limit the scope and severity of further impacts – and that is virtually certain.

Resources:

- Union of Concern Scientists - http://www.ucsusa.org/global_warming/
- http://www.paseagrant.org/fact_sheet_group/invasive-species/
- Original More or Less Activity - COSEE Great Lakes: http://greatlakesliteracy.net/_downloads/activities/gw-more-less.pdf
- PA Sea Grant/Erie Times-News in Education pages Climate change/AIS pages can be found in the resource folder.



This lesson is one of 10 lessons that focus on climate change and invasive species prepared by the Pennsylvania and New York Sea Grant programs as part of a larger Great Lakes Sea Grant Network initiative funded by the Great Lakes Restoration Initiative.