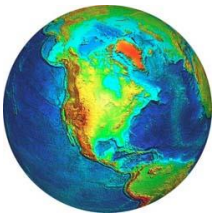


Making Connections: Climate Change and AIS

Overview:

Drawing connections is a helpful way to classify and interact with information. In this lesson plan students work in pairs or small teams to generate a list of glossary words on climate change and aquatic invasive species, then group the terms into helpful categories.

Summary:

This lesson plan suggests one way to help students interact with new material. They will list vocabulary words they already know about climate change and aquatic invasive species, and sort those words into related groups. Then as they learn new words, students will add them to the groups of words they already know.
Estimated class time: one class period for the initial lesson, plus one optional class period at the end of the unit.

Objectives:

At the conclusion, students will be able to:

- Summarize information they already know
- Use this information to develop a framework they can use to add new information as they learn it
- Become more familiar with climate change and aquatic invasive species
- Be able to associate a definition with its term
- Use relevant vocabulary accurately for reading and oral and written communication
- Become familiar with the words (or labels for concepts) and their meaning, thereby increasing their understanding of environmental issues
- Recognize some common native and invasive species in the Great Lakes

Standards:

Subject Areas: Science, Social Studies, and Language Arts
Standards for Language Arts, K-12 (National Council of Teachers of English):

- Students apply a wide range of strategies to comprehend, interpret, evaluate, and appreciate texts. They draw on their prior experience, their interactions with other readers and writers, their knowledge of word meaning and of other texts, their word identification strategies, and their understanding of textual features (e.g., sound-letter correspondence, sentence structure, context, graphics).
- Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences for a variety of purposes.
- Students use newspaper articles and suggested websites to gather and synthesize information and to create and communicate knowledge.

Materials:

- Blackboard, dry erase board, or large sheets of paper
- Writing utensils/paper for each small group or pair
- PA Sea Grant/Erie Times-News NIE pages found in the resource section. These pages have articles and suggested websites to learn more about climate change and AIS.

Procedure:

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

1. Can they name any invasive species? Do they know the issues caused by those species or what people are doing to control them?
2. 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?
3. Brainstorm with the whole group all the words they can think of that are associated with climate change and invasive species, and write them on the board.
4. Have students work in pairs or small teams to place the words into groups based on something the words have in common (several groupings are usually possible, and some words may fit into more than one group).
5. Once all the student pairs or teams have finished, ask them to share their word groupings and reasoning behind their decisions.
6. Have students go back with their team to choose labels for each group of words. Then have them share, and discuss why they chose the labels.
7. Finally have students read the PA Sea Grant/Erie Times-News NIE pages about climate change and aquatic invasive species and ask them to add new words to their groupings and create new word groups if necessary.

Extension Activities:

- Have students try to regroup their words in different ways, challenging them to find new pathways for connecting words and concepts.
- To stimulate other ways of thinking about the information (and multi-sensory learning), have students think of a nonlinguistic way (such as an image, action, or sound) to represent each group.

Assessment:

- Creation of board containing all glossary terms, spelled correctly
- Correct use of definitions
- Listening and participating when others read back their terms and definitions

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.

Great website where students can hear the words and definitions
http://quizlet.com/19281205/climate-change-vocabulary-flash-cards/

Climate change Terms	Definitions
Adaptation	the responsive adjustment of a sense organ (such as the eye) to varying conditions; the process of adapting to something (such as environmental conditions)
Acclimatize	to adjust to changes in environmental variables
Atmosphere	The area in which all air exists; this sphere contains all of the gases that surround the earth
Anthropogenic	having to do with man, or caused by humans
Methane	an odorless, colorless, flammable gas, CH_4, the major constituent of natural gas, that is used as a fuel and is an important source of hydrogen and a wide variety of organic compounds
Mitigation	to act in such a way as to cause an offense to seem less serious. Related to climate change, mitigation refers to actions that reduce greenhouse gas emissions at their source; or actions that remove greenhouse gases from the atmosphere
Particulate matter	small particles of matter such as dust and soot that are suspended in the air
Per capita	per unit of population (per person)
Weather	short-term (daily) changes in temperature, wind and/or precipitation in a region
Vulcanism	Those processes collectively that result in the formation of volcanoes and their products
Urban heat island	A region of warmer air temperature (relative to the surrounding countryside) in a metropolitan area. Urban heat islands have been documented to exist in cities with as few as a thousand inhabitants
Topography	Having to do with elevation or "lay of the land," i.e., surface features
Stakeholder	Those individuals, groups, organizations and/or

	institutions that have a role in the problem and/or its solution and a stake in the outcome
Shade-tolerant species	Plants that typically grow in places that receive less than full sunlight, such as the lower levels of a forest; they generally have low relative growth rates, open stomata, and thick densely-packed leaves
Shade-intolerant species	Plants that typically grow in places that receive lots of direct sunlight; they generally have high relative growth rates, highly-regulated stomata, and thin leaves.
Quad	A quadrillion BTUs, or the energy required to raise one quadrillion gallons of water one degree Fahrenheit. It is roughly equivalent to 1.05 x 10^18 joules
Proxy Data	Data obtained from objects that are sensitive to climatic phenomena; some examples are tree ring widths, ice cores, pollen deposits, glacier lengths and deep sea sediments. Analyses of such data can be used to provide estimates of past climate conditions, such as temperature, precipitation or wind speed.
Precipitation Efficiency	The efficiency with which atmospheric moisture is converted to precipitation, often described as the ratio of precipitation to total available moisture
Precipitation	The movement of liquid or solid water (rain, sleet, snow, etc.) from the atmosphere to the Earth's surface; precipitate (verb)
Preferred Action	What the stakeholder thinks should be done about the specific issue; what action, if any, the stakeholder says should be taken
Plate Tectonics	A theory explaining the present and past locations of continents due to massive movement of the Earth's crust
Photosynthesis	The process by which plants use sunlight, water and carbon dioxide to produce their food
Parts per million (ppm)	Unit of measure most often used to describe the amount of a particular gas or compound in the air or water; it is the proportion of the number of molecules of the gas or compound out of a million (1,000,000,000) molecules of air or water

Permafrost	Ground that is permanently frozen
Isostatic Sea Level Change	Changes in sea level caused by the rising or falling of various portions of the earth's crust.
Interest	An immediate underlying concern applied to a specific situation or issue that usually reflects a person's personal interest or motivation; competing interests result from a difference in perspective and motivation
Ice Age	A period of extensive glaciations over large portions of earth's continents accompanied by reduced global temperature and changes in atmospheric circulation
Hypothesis	A supposition or idea about something; in the scientific realm, it generally relates to physical or chemical interactions among various entities of nature
Hydrosphere	Area in which water exists; for the purpose of this module, this sphere includes all liquid water on Earth, such as rivers, lakes and oceans, all frozen waters such as glaciers, icebergs, and polar icecaps, and water vapor
Hurricane	A tropical cyclone with winds in excess of 64 knots (74 mph)
Gross Domestic Product (GDP)	This is one way to measure the size of an economy; it is the market value of all final goods and services within a country in a given period of time
Greenhouse gases	Gases such as water vapor, carbon dioxide and methane that are relatively transparent to the short wavelength solar radiation that emanates from the sun but that are fairly opaque to the longer wavelength thermal radiation that emanates from the surface of a planet. Other greenhouse gases include Nitrous Oxide, HFC's, SF6 and CFC's but will not be covered in depth in this unit.
Global Climate Change	A change in the long-term weather patterns that is characteristic of regions of the world
Global carbon cycle	The cyclical movement of carbon within the biosphere; carbon is primarily removed from the air by plants during photosynthesis and by dissolving in bodies of water. Carbon is generally returned to the air via biological respiration, decomposition of organic matter, volcanic activity and society's industrial activities, including the combustion of fossil fuels.

Fossil fuels	Deposits of organic matter that have been altered over geologic time (since the Earth's formation) and can be burned for energy; for example, coal, crude oil and natural gas
Food Chain	A sequence of organisms in an ecosystem in which each member feeds on the member below it
Fixed	A shorthand term for the "fixation of carbon," which is the process by which plants remove CO_2 from the air and incorporate it into their tissues
Fixation of Carbon	Another name for the photosynthetic process, whereby carbon is removed from the air and "fixed" or incorporated into plant tissues
Eustatic Sea Level Change	Changes in sea level caused by changes in the water volume of the world's oceans, such as those brought about by the formation or melting of mountain glaciers and polar ice caps
Emission	Substance that is released or discharged, usually into the air; emit (verb)
Evaporation	The movement of gaseous water (water vapor) from the Earth's surface to the atmosphere; evaporate (verb)
Ecosystems	Communities of plants, animals and bacteria, generally composed of producers, consumers and decomposers that share a common physical and chemical environment
Deforestation	The removal of trees from a previously pristine area, generally by logging to obtain lumber products
Cyclone	An area of low-pressure often associated with stormy weather
Cryosphere	The sum total of earth's fresh water supply that is locked up in frozen forms including polar ice, mountain glaciers, permafrost and snow
CO_2 Sequestration	The process of removing carbon dioxide from the atmosphere and making it unavailable for release back to the air

Climate	Long-term pattern of weather that characterizes a region
Chlorofluorocarbon (CFC)	Anthropogenic aerosol compound containing chlorine, fluorine and carbon that is used in propellants, refrigerants and solvents; freon
Carbon Source	A place where carbon is produced or released; for example, plants release carbon in the form of carbon dioxide when their tissues are broken down during combustion. In addition, cars release carbon dioxide as they burn gasoline, and power plants release carbon dioxide when they burn fossil fuels to generate electricity.
Carbon Sink	A place where carbon accumulates and is stored. For example, plants and trees are carbon sinks; they accumulate carbon dioxide during the process of photosynthesis and store it in their tissues as carbohydrates and other organic compounds.
Carbon Dioxide (CO_2)	A colorless, odorless, incombustible gas. CO_2 is formed during respiration, combustion and organic decomposition, and used in food refrigeration, carbonated beverages, inert atmospheres, fire extinguishers and aerosols
Biosphere	The area in which all living things exist; this sphere includes all of the microorganisms, plants and animals of Earth, even humans
Biome	Major division of the ecological communities on Earth characterized by the plant and animal life of that region
Biodiversity	A property of ecosystems related to the number of different plant and animal species they contain
Limiting factor	A resource that is needed by a species to survive in its habitat, a shortage of which limits the species' population
Competition	When multiple individuals seek the same limited resource

Native species	Species that occur naturally in an area
Non-native species	Species that do not come from the area or region from which they are found growing
Invasive species	A type of non-native species that is taking over the habitat that it was introduced to
Population	A certain sized group of individuals of the same species in a habitat

A Glossary of More Terms Related to Invasive Species Ecology

Alien species: Less commonly used in scientific literature, but often in popular publications, public information displays, and educational literature, this term refers to species that spread beyond their native range, not necessarily harmful; or species introduced to a new range that establish themselves and spread; similar terms include exotic species, foreign species, introduced species, non indigenous species, and non native species (Jeschke and Strayer 2005).

Aquatic nuisance species: Less commonly used in most literature. 1. A nonindigenous species that threatens the diversity or abundance of native species or the ecological stability of infested waters, or commercial, agricultural, aquacultural or recreational activities dependent on such waters (EPA 1990). 2. Aquatic species that causes economic or environmental harm to humans (Heutte and Bella 2003). 3. An aquatic species with adverse effects on humans, either directly (e.g. species that produce toxins that are harmful to humans) or indirectly (e.g. species that infest nature reserves) (Colautti and MacIsaac 2004).

Biological control or biocontrol: 1. In general, the control of the numbers of one organism as a result of natural predation by another or others; specifically, the human use of natural predators for the control of pests or weeds. Also applied to the introduction of large numbers of sterilized males of the pest species, whose matings result in the laying of infertile eggs (Allaby, 1998). 2. The release of one species to control another (Carlton, 2001). 3. The management of weeds using introduced herbivores (often insects) as biological control agents (Booth et al., 2003). 4. Control method involving a biological control agent that is a natural enemy of a target pest (Heutte and Bella, 2003).

Biological invasion or bioinvasion: A broad term that refers to both human-assisted introductions and natural range expansions (Carlton, 2001)

Biological diversity or biodiversity: Used to describe species richness, ecosystem complexity, and genetic variation (Allaby 1998)

Bioregion: A biological subdivision of the earth's surface delineated by the flora and fauna of the region (Allaby 1998)

Biota: The plants and animals of a specific region or period, or the total aggregation of organisms in the biosphere (Allaby 1998)

Casual species: This term is becoming less common in usage; a non native species that does not form self-replacing populations (Booth et al. 2003). Similar terms include introduced species, non indigenous species, and non native species.

Chemical control: The use of chemicals to kill pests; control method that employs herbicides to control exotic plants (Heutte and Bella 2003);

Community: Any grouping of populations of different organisms that live together in a particular environment (Allaby 1998)

Cryptogenic species: Species that are neither clearly native nor exotic (Cohen and Carlton 1988)

Cultivar: A variety of a plants produced and maintained by horticultural techniques and not normally found in wild populations (Allaby 1998)

Disturbance: An event or change in the environment that alters the composition and successional status of a biological community and may deflect succession onto a new trajectory, such as a forest fire or hurricane, glaciation, agriculture, and urbanization (Art 1993)

Ecosystem: A discrete unit, or community of organisms and their physical environment (living and non-living parts), that interact to form a stable system (Allaby 1998)

Endemic: A species or taxonomic group that is restricted to a particular geographic areas because of such factors as isolation or response to soil or climatic conditions; this species is said to be endemic to the place (Allaby 1998) and would be native

Exotic species: This term is commonly used in publications and literature, and is similar to the terms alien species, foreign species, introduced species, non indigenous species, and non native species (Heutte and Bella 2003); other definitions include: 1. An introduced, non native species, or a species that is the result of direct or indirect, deliberate or accidental introduction of the species by humans, and for which

introduction permitted the species to cross a natural barrier to dispersal (Noss and Cooperrider 1994). 2. In North America, often refers to those species not present in a bioregion before the entry of Europeans in the 16th century, or present in later parts of that region and later introduced to an ecosystem by human-mediated mechanisms (Cohen and Carlton 1988).

Fauna: The animal life of a region or geological period (Allaby 1998)

Foreign species: A species introduced to a new area or country. Similar terms include alien species, exotic species, introduced species, non indigenous species, and non native species

Flora: Plant or bacterial life forms of a region or geological period (Allaby 1998)

Habitat: The place, including physical and biotic conditions, where a plant or an animal usually occurs (Allaby 1998)

Herbicide: Pesticide that specifically targets vegetation (Heutte and Bella 2003)

Indigenous: A species that occurs naturally in an area; a synonym for native species (Allaby 1998), although see "endemic"

Injurious species: An introduced species that causes economic or environmental harm to humans; similar terms include aquatic nuisance species, noxious weed, and invasive species (Heutte and Bella 2003)

Intentional introduction: A species that is brought to a new area, country, or bioregion for a specific purpose, such as for a garden or lawn; a crop species; a landscaping species; a species that provides food; a groundcover species; for soil stabilization or hydrological control; for aesthetics or familiarity of the species; or other purposeful reasons (Booth et al. 2003)

Introduced species: This term, along with the terms introduced species and nonindigenous species, is one of the most commonly used terms to describe a plant or animal species that is not originally from the area in which it occurs; this terms means those species that have been transported by human activities, either intentionally or unintentionally, into a region in which they did not occur in historical time and are now reproducing in the wild (Carlton 2001). Similar terms include alien species, exotic species, foreign species, non indigenous species, and non native species.

Invasibility: The ease with which a habitat is invaded (Booth et al. 2003)

Invasion: The expansion of a species into an area not previously occupied by it (Booth et al. 2003)

Invasive species: This term is subject to the most confusion and debate within invasion biology terminology. Generally, this term refers to a subset of plants or animals that are introduced to an area, survive, and reproduce, and causes harm economically or environmentally within the new area of introduction. 1. An alien species whose introduction does or whose introduction is likely to cause economic or environmental harm or harm to human health (Executive Order 1999). 2. An adjective for native or nonindigenous species that have colonized natural areas; 3. Discrimination of nonindigenous species established in cultivated habitats (as 'noninvasive') from those established in natural habitats; 4. Nonindigenous species that are widespread; or 5. Widespread nonindigenous species that have adverse effects on the invaded habitat (Colautti and MacIsaac 2004). Other definitions include the following: 5. Species that spread beyond their native range, not necessarily harmful, or species introduced to a new range that establish themselves and spread (Jeschke and Strayer 2005). 6. Species that displace native species and have the ability to dominate an ecosystem, or a species that enters an ecosystem beyond its natural range and causes economic or environmental harm (Heutte and Bella 2003).

IPM: Integrated Pest Management. IPM focuses on long-term prevention or suppression of pests. The integrated approach to weed management incorporates the best suited cultural, biological and chemical controls that have minimum impact on the environment and on people (Heutte and Bella 2003).

Manual control: Species removal that involves the use of tools; for example, tools such as shovels, axes, rakes, grubbing hoes, and hand clippers to expose, cut, and remove flowers, fruits, stems, leaves, and/or roots from target plants (Heutte and Bella 2003)

Mechanical control: Removal that involves the use of motorized equipment such as mowers, "weed-whackers", and tractor-mounted plows, disks, and sweepers. Burning is also categorized here (Heutte and Bella 2003).

Native range: The ecosystem that a species inhabits (Booth et al. 2003)

Native species: 1. A synonym for indigenous species 2. A species that occurs naturally in an area, and has not been introduced by humans either intentionally or unintentionally (Allaby 2005). 3. In North America, a species established before the year 500 (Jeschke and Strayer 2005)

Native weed: A species that is native to an area or bioregion that has increased in number dramatically; in cases of disturbance or change to a landscape, a ruderal species can increase in cover and compete with other native plants, threatening members of the community. In other cases, landscape level changes can cause the increase of the population of a species, such as white-tailed deer in the northeastern part of the United States, which are at the highest levels historically and cause damage to humans, crops, and structures, suffer high disease levels, and pose threats to humans through interactions on roads (Foster and Sandberg 2004).

Naturalized species: 1. A species that was originally introduced from a different country, a different bioregion, or a different geographical area, but now behaves like a native species in that it maintains itself without further human intervention and now grows and reproduces in native communities (Allaby 1998). 2. A non native species that forms self-sustaining populations but is not necessarily an invasive species (Booth et al. 2003)

Niche opportunity: Defines conditions that promote invasions in terms of resources, natural enemies, the physical environment, interactions between these factors, and the manner in which they vary in time and space (Shea and Chesson 2002)

Nonindigenous species: This is a common term used along with non native species and introduced species in current literature and publications; other similar terms include alien species, exotic species, and foreign species. 1. Any species or other viable biological material that enters an ecosystem beyond its historic range, including any such organism transferred from one country into another (EPA 1990). 2. A plant or animal that is not native to the area in which it occurs that was either intentionally or unintentionally introduced (Williams and Meffe 2005)

Non native species: This term, along with the terms introduced species and nonindigenous species, is one of the most commonly used terms to describe a plant or animal species that is not originally from the area in which it occurs. Similar terms also include alien species, exotic species, and foreign species. This term has also been defined as: 1. A species whose presence is due to intentional or unintentional introduction as a result of human activity (Booth et al. 2003). 2. A species that has been introduced to an area or bioregion (Heutte and Bella 2003).

Noxious weed: This term is frequently a legal term in state code, denoting a special status of the plant as, for example, prohibited or restricted. 1. Native or non-native plants, or plant products, that injure or cause damage to interests of agriculture, irrigation, navigation, natural resources, public health, or the environment (Heutte and Bella 2003). 2. Implies a species' adverse effects on humans, either directly (e.g. species that produce toxins that are harmful to humans) or indirectly (e.g. species that infest nature reserves) (Colautti and MacIsaac 2004). 3. Any species of plants, either annual, biennial, or perennial; reproduced by seed, root, underground stem, or bulblet; which when established is or may become destructive and difficult to control by ordinary means of cultivation or other farm practices (Heutte and Bella 2003)

Pathway: 1. Used to mean vector, purpose (the reason why a species is moved), and route (the geographic corridor from one point to another) (Carlton 2001). 2. Mode by which a species establishes and continues to exist in a new environment (Heutte and Bella 2003)

Pest: 1. An animal that competes with humans by consuming or damaging food, fiber, or other materials intended for human consumption or use, such as an insect pest on a cropfield (Allaby 1998) 2. Synonymous to invasive species (Jeschke and Strayer 2005).

Pesticide: A chemical or biological agent intended to prevent, destroy, repel, or mitigate plant or animal life and any substance intended for use as a plant regulator, defoliant, or desiccant, including insecticides, fungicides, rodenticides, herbicides, nematocides, and biocides (Heutte and Bella 2003)

Population: A group of potentially inter-breeding individuals of the same species found in the same place at the same time (Booth et al. 2003)

Prohibited weed: A specific legal term applied to a plant or plant part that may not be brought into a state (Heutte and Bella 2003)

Restricted weed: A specific legal term applied to a plant or plant part that may only be brought into a state in limited quantities (Heutte and Bella 2003)

Ruderal species: A plant associated with human dwellings, construction, or agriculture that usually colonizes disturbed or waste ground. Ruderals are often weeds which have high demands for nutrients and are intolerant of competition. See also native weed or invasive native (Allaby 1998).

Seed bank: Seeds that become incorporated into the soil (Booth et al. 2003)

Species: A group of organisms formally recognized as distinct from other groups; the taxon rank in the hierarchy of biological classification below genus; the basic unit of biological classification, defined by the reproductive isolation of the group from all other groups of organisms (Allaby 1998)

Tens rule: 1. Describes how approximately ten percent of species pass through each transition from being imported to becoming casual to becoming established, and finally becoming a weed (Booth et al. 2003) 2. Ten percent of the introduced species establish themselves in the non native continent and ten percent of these, in turn, spread or are pests (Jeschke and Strayer 2005). {note that J&S found exceptions to the 10's rule}

Time lag: 1. Time between introduction, establishment, and spread (Jeschke and Strayer 2005) 2. The time between when a species is introduced and when its population growth explodes (Booth et al. 2003)

Unintentional introduction: An introduction of nonindigenous species that occurs as the result of activities other than the purposeful or intentional introduction of the species involved, such as the transport of nonindigenous species in ballast or in water used to transport fish, mollusks or crustaceans for aquaculture or other purposes (EPA 1990)

Vector: The physical means or agent by which a species is transported, such as ballast water, ships' hulls, boats, hiking boats, cars, vehicles, packing material, or soil in nursery stock (Carlton 2001) See also Pathway

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?

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 (CO_2) 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 activity is 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:

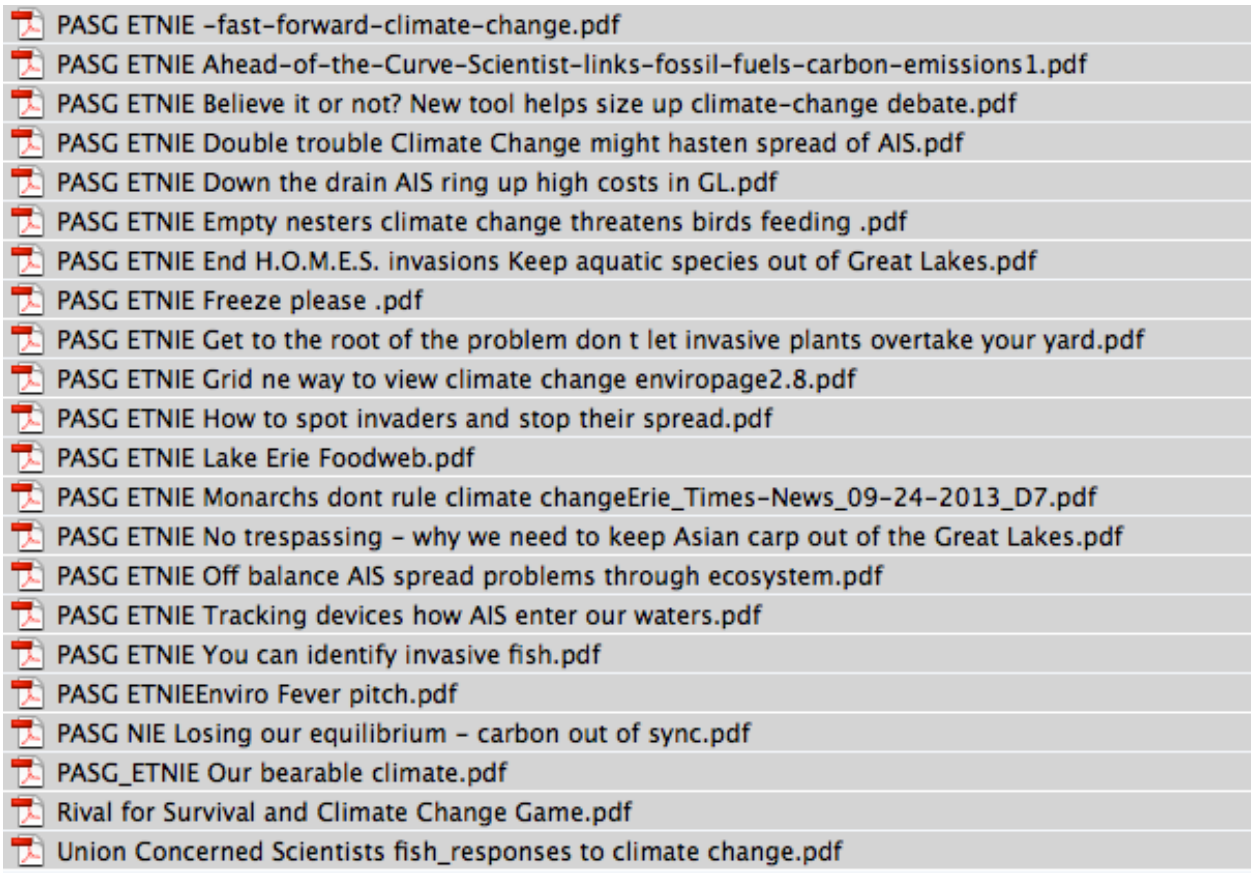
- Human-induced warming influences physical and biological systems throughout the world
- Sea levels are rising
- Glaciers and permafrost are shrinking
- Oceans are becoming more acidic
- Ranges of plants and animals are shifting

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/
- PA Sea Grant/Erie Times-News in Education pages Climate change/AIS pages listed below can be found in the resource folder.



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