UNIT 2

Energy & the ecosystem

The energy of eating, growing, living, and dying

Energy is everywhere and always in circulation on Jones Beach, passing among hundreds of organisms through a network of relationships of consumption called the “food web.” This is the infrastructure at the heart of all ecosystems, which allows energy to flow along similar pathways in radically different environmental contexts. “Primary producers” transform radiant energy from the sun into chemical energy through photosynthesis, which is digested, used, and stored by successive rounds of consumers and then dissipated into the environment in the form of heat as decomposers dismantle dead organic matter. But this cycle is vulnerable to disruption, as interference with one species’ ability to access the energy it needs to thrive and reproduce can threaten the survival of entire ecological communities. From the beachfront to the dunes, from the Pollinator Garden to the marsh, the many ecosystems of Jones Beach are an ideal setting to explore these interdependent relationships and the human activities that influence them.

As a barrier island, Jones Beach also illustrates how energy produces the abiotic conditions and terrain that are the foundation of any ecosystem. Perhaps the most fundamental way that energy impacts and moves through the environment is in the form of forces that literally shape land and distribute water. On Jones Beach, the kinetic energy of wind and waves both build up and erode the beach and dunes, creating a dynamic shoreline that is constantly in flux. Meanwhile, the energy of solar radiation drives the water cycle and determines seasonal temperature and precipitation patterns that add up to the local climate. As greenhouse gas emissions trap increasing amounts of solar radiation within Earth’s atmosphere, that energy causes polar and glacial ice to melt, in turn causing sea levels to rise across the world. With sea levels rising faster than average at Jones Beach, this is also a place to think through the local consequences of human activity on a global scale.

In this Unit, students use the different ecosystems of Jones Beach to explore the various ways that energy moves through and shapes an environment populated by communities of plants, animals, and other organisms that all depend on one another for survival. Hands-on activities help students assume the perspectives of the organisms themselves, as well as those of concerned scientists trying to understand how human activities threaten interdependent ecological networks. Research projects and reading responses engage analytical and critical-thinking skills as students explore the complex webs of energy and nature that support all forms of life.

Objectives

Identify the different functions performed by different species in an ecosystem, and describe chains of energy production and consumption within an ecosystem.

Articulate how energy loss in transfer between trophic levels operates as population control.

Describe relationships of interdependence within ecosystems beyond the food web.

Explore human impacts on ecosystems and articulate why human impacts can be more destructive to ecosystems than naturally-occurring environmental disturbances.

Analyze how energy locally drives weather and globally determines climates, and examine the relationship between global climate change and local conditions.

Critically assess different conceptual frameworks for understanding interdependence and the importance of ecosystems to human life.

Learning standards

The materials in this Unit correspond with the following New York State P-12 Science Learning Standards and elements of the New York State Grades 9-12 Social Studies Framework.

New York State P-12 Science Learning Standards

LS1-5 LS1-6 LS2-1 LS2-2 LS2-3 LS2-4 LS2-5 LS2-6 LS2-7 LS2-8 LS4-4 LS4-5 ESS2-1 ESS2-5 ESS2-7 ESS2-8 ESS3-5 ESS2-8

Social Studies Framework

Practices | A1 A2 A5 A6 B3 B4 B7 C1 C5 C6 D1 D2 D3 D4 D5 D6 E2 E5 E6 F2 F6 F7 F8

Themes | GEO EXCH

More information:

nysed.gov/curriculum-instruction/science-learning-standards

nysed.gov/curriculum-instruction/k-12-social-studies-framework

Key terms

Ecosystem
Biome
Ecosystem resilience
Ecological niche

Biodiversity
Invasive species
Keystone species
Succession events

Food web
Trophic levels
Autotroph
Photoautotroph
Photosynthesis
Heterotroph
Primary energy consumer
Secondary energy consumer

Interdependence
Symbiosis
Amensalism
Commensalism
Mutualism
Parasitism

Carnivore
Herbivore
Omnivore
Pollination

Migration
Predator
Prey
Scavenger
Decomposer
Detritivore
Organic matter and biomass

Abiotic factors
Water cycle
Carbon cycle
Carbon reservoirs/sinks
Nitrogen cycle
Nitrogen fixation
Nutrient pollution
Eutrophication
Anthropogenic disturbance
Enhanced greenhouse effect

Barrier island
Long-shore current
Overtopping
Erosion
Storm surge
Conservation
Habitat restoration
Remediation

CORE CONCEPT 1

Energy cycles among organisms in the ecosystem

Energy enters natural systems primarily as sunlight, which is harnessed through photosynthesis and conveyed between trophic levels in the food web.

Sean Hanley and G. Anthony Svatek

Energy and the food web

In this Core Concept, students use the food web as a framework to explore the multiple ecosystems of Jones Beach. They come to understand that all ecosystems are built around the same set of fundamental relationships between organisms, and that different organisms in different ecosystems can fill similar "ecological niches" based on their role and relationship to others.

An initial short discussion establishes baseline vocabulary. Then, in a scavenger-hunt activity, students use the exhibits at the Jones Beach Energy & Nature Center to construct a map of the surrounding ecosystems and the organisms comprising each. Students' new familiarity with the geography of the Center and its surroundings provides the basis for a group discussion that establishes the different environmental and biological factors governing the feeding patterns and energy requirements of different organisms. Students begin to articulate how redundancy and biodiversity are important characteristics of resilient ecosystems. Next, an interactive role-play activity allows students to explore how energy producers and consumers at different trophic levels can coexist in relatively stable populations. Embodying different actors from the local salt marsh ecosystem, students experience first-hand how the ecosystem seeks a self-sustaining equilibrium, and how disturbances can throw that equilibrium out of balance.

For a final, take-home activity, students exercise their research, critical thinking, and analytical skills to connect the transfer of energy in ecosystems with the use of energy as a tool in human societies. Research questions guide students to draw connections between the production of chemical energy by photosynthesizing plants and phytoplankton, the formation of hydrocarbons through millennia of organic pressure, and attempts to find a "sustainable" fuel alternative based on cultivated corn and algae.

What is an ecosystem?

What is an ecosystem?

What are examples of ecosystems?

Think about Jones Beach: is this place all one ecosystem, or several?

An ecosystem is a geographical area with a particular set of environmental characteristics inhabited by a relative stable community of organisms that interact with and depend on one another in various ways. Different kinds of ecosystems are replicated in similar climates around the world, with species specific to each geography performing similar functions; large areas of shared climate conditions, meanwhile, are called biomes. Tundra, rain forest, grassland, and coral reef are examples of biomes that exist in multiple places on Earth. Each of these has its own ecosystem communities of distinct, but analogous, species.

Jones Beach is a barrier island made up of several ecosystems, each defined by specific natural conditions and the distinct set of organisms that live there. These systems include the beach, the primary dune, the interdunal swale, the secondary or back dune, the salt marsh, the bay, and the open ocean. However, the boundaries of these ecosystems are porous, and some species move between them — or, in the case of migratory animals, between these ecosystems and others far away.

PRIMER

Give students a few minutes to respond, either alone or in small groups. Then move into the next activity by inviting students to share their answers.

AT THE CENTER

Groups working with the curriculum on site can use the Jones Beach: Home and Hotel and Pollinator Garden exhibits to complete the scavenger hunt, referring to the Map of Exhibits included in the Introduction to the Curriculum..

Groups working off site can use a biodiversity database like iNaturalist to complete the activity.

inaturalist.org

For full activity materials, see:

Unit 2 Appendix Pages 2-3

Who makes up this ecosystem?

All organisms require energy to grow and reproduce. In an ecosystem, organisms are often defined by how they obtain energy and their relationship to one another in a network of energy production and consumption — also known as the food web. Each organism in a food web is categorized according to its role in energy production and consumption, also called its trophic level.

Organisms that turn nonliving material and phenomena like sunlight, carbon dioxide, or heat into chemical energy are called energy producers, or autotrophs.

Some autotrophs transform radiant energy from the sun into chemical energy through the process of photosynthesis — these are called photoautotrophs. They are often plants, but algae, seaweed, and some bacteria are also photoautotrophs.

Find a photoautotroph...

in the garden.

Examples: Evening Primrose; Black-Eyed Susan; Common Milkweeds.

on the beach or in the dunes.

Examples: American Beachgrass; Bayberry; Seaside Goldenrod.

in the marsh.

Examples: Smooth Cordgrass; Salt Meadow Cordgrass.

in the ocean.

Examples: Eelgrass; seaweeds; phytoplankton.

Chaetoceros debilis
Courtesy University of British Columbia Phyto'Pedia Project

Atlantic Blue Crab
Jeremy Thorpe

Organisms that feed on others to obtain energy are called heterotrophs. They are often animals but can also be fungi, bacteria, or slime molds.

Heterotrophs that feed only on autotrophs are called primary energy consumers. Animals that feed only on plants or fungi are called herbivores.

Find a primary consumer...

in the garden.

Examples: Eastern Cottontail Rabbit; hummingbirds; bees and butterflies.

on the beach or in the dunes.

Examples: Seaside Grasshoppers; Monarch Butterflies.

in the marsh.

Examples: Crabs, snails, and mollusks like Quahogs or Ribbed Mussels.

in the ocean.

Examples: Krill and other small zooplankton.

There seem to be relatively few herbivorous primary consumers in the marine ecosystems near Jones Beach. Why is this the case?

Energy production by photoautotrophs is limited by the availability of light and nutrients, which are generally less available in the North Atlantic than on land at Jones Beach. The salt marsh can demonstrate this principle as well: photoautotrophs are generally more densely abundant there than in the ocean, as nutrients and light are relatively more available in the brackish, shallow water.

Most marine photoautotrophs are microbial algae and bacteria called phytoplankton. But most marine animals in the North Atlantic are omnivores or carnivors, as they cannot derive all the energy they need to move and reproduce from these tiny primary producers alone. Herbivorous fish are more common in tropical ocean waters, where sunlight is more plentiful and fish play an important role in managing photoautotroph populations. In the waters near Jones Beach, phytoplankton are the primary energy source for zooplankton like krill, also microscopically small. Together these communities of tiny organisms form the basis of the local marine food web. Mollusks like oysters and mussels are "filter feeders," straining chemical nutrients and plankton from the water.

Heterotrophs that feed on other heterotrophs are called secondary energy consumers. Animals that feed both on plants and other animals are called omnivores. Those that feed exclusively on other animals are called carnivores. Whenever a secondary energy consumer kills and eats another energy consumer, they become a predator. The animal that is eaten is prey.

Find a secondary consumer...

in the garden.

Examples: The Hognose Snake preys on amphibians, especially toads, while the Fowler's Toad eats insects. Larger birds like the Great Egret and the Northern Harrier prey on fish, amphibians, invertebrates, and small mammals. Smaller birds may eat insects in addition to plant materials.

on the beach or in the dunes.

Examples: Shorebirds like the Piping Plover prey on insects and invertebrates that live in the sand along the waterline. Birds of prey like Snowy Owls hunt small mammals and birds.

in the marsh.

Example: Birds like Osprey, Great Egrets, and ducks prey on many different kinds of fish and invertebrates. Fish may prey on invertebrates, mollusks, crabs, and smaller or juvenile fish. Crustaceans may prey on smaller fish, invertebrates, and mollusks.

in the ocean.

Examples: Whales and sharks are top predators, but most sea creatures survive by preying on smaller marine animals.

What characteristics do predators tend to have in common?

Generally speaking, organisms exist in different scales within a single ecosystem. Think of the difference between an earthworm and an eagle, in terms of the space they occupy and traverse. The larger an animal is relative to other organisms at its scale, the more energy it requires to maintain its body, move around, and reproduce. Thus, the larger the animal, the more likely it is to consume other animals within its scale in order to meet its energy needs. (This is because proteins and fats, which are most of animals' bodies, are more energy-dense on a molecular level than the carbohydrates that plants are made of).

Certain physical traits may also be consistent across predatory animals: sharp teeth, claws, or beaks allow them to wound and kill prey, as well as dismantle their prey's bodies in order to eat them. Speed and the ability to locate and hunt prey from a distance – whether flying, stalking, or chasing – are advantageous. Some predators produce natural venoms or traps, like spider webs, to catch prey. Others have colorings or markings that allow them to blend into their environments, where they can lay in wait for prey to cross their paths.


Great Egret
Amy Schiffers


American Lobster
Derek Keats


Fowlers Toad
Scott Hecker

Herring Gull
David Nikolai Kastrup

Heterotrophs that feed on organic matter and biomass (waste and dead matter) are called detritivores. Organisms that passively break down dead matter, like bacteria and fungi, are more specifically called decomposers. Animals that feed on the remains of other animals, often left over from predation, are called scavengers.

Find a detritivore or scavenger...

on land.

Examples: Raccoons; Herring Gulls; Green Darners; Atlantic Sand Fiddler Crabs; worms; flies.

in the water.

Examples: Vampire squids; Periwinkle Snails; marine worms; crustaceans like lobsters and crabs; American Eels.

Why are detritivores and decomposers important to an ecosystem?

Organisms need more than just energy in order to grow, maintain themselves, and reproduce. They also need nutritional building-blocks like carbon, nitrogen, oxygen, water, and mineral nutrients. Organisms that derive energy from dead organic matter also effectively "recycle" the dead matter into its component materials, which are then released into the environment and made available for uptake by other organisms. Earthworms are a good, intuitive example of how this works: often, people who are trying to make compost from waste vegetative material add worms to their pile in order to facilitate the transformation of decaying organic matter into nutrient-rich soil.

Organisms in an ecosystem can also be described in terms of relationships with one another that don't involve eating or being eaten.

Symbiosis describes any close and long-term biological relationship between two organisms.

In symbiosis, when both organisms benefit, this is mutualism.

When one of the organisms benefits and the other is harmed, this is parasitism.

When one of the organisms benefits and the other is unaffected, this commensalism.

When one of the organisms is harmed and the other is unaffected, this is amensalism.

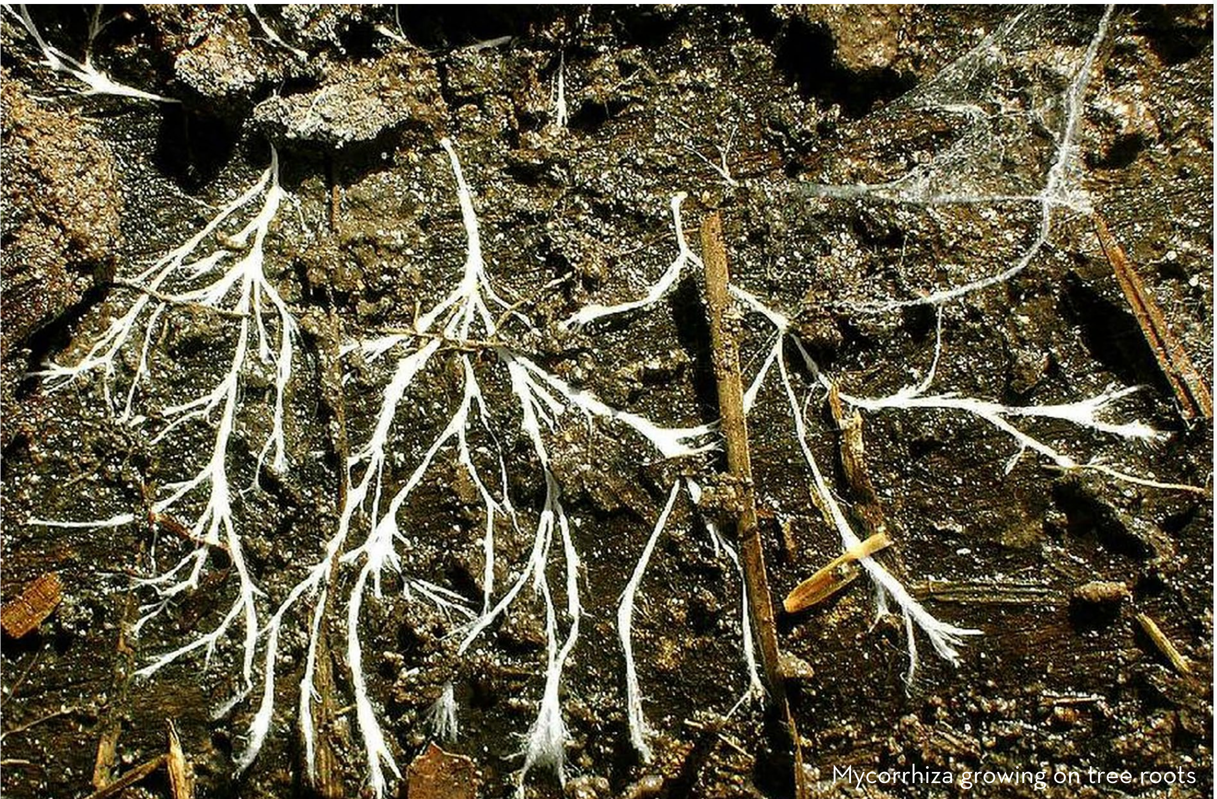
A common form of symbiosis is pollination. Animals that get their energy from plants help those plants reproduce as they feed, by carrying pollen between the plants they visit, allowing seeds to be fertilized.

Find two examples of pollinators and the plants they pollinate in the ecosystems of Jones Beach.

Example pollinators: Monarch Butterflies; Luna Moths; Bees; Hummingbirds. They pollinate: Seaside Goldenrod, Common Milkweed, Evening Primrose, and various other flowering plants.

Find another example of symbiosis between organisms. What kind of symbiotic relationship is this?

Examples: Mycorrhizae are fungi that attach to plant roots and funnel water and nutrients toward the plants while drawing photosynthesized chemical energy from the plants. This is a form of mutualism. Mussels and cordgrass in marshes are also mutualistic; the mussels draw nutrients out of the water and channel them into plant, while the plant provides the mussels with shade and protection from predators.



Mycorrhiza growing on tree roots

Sometimes, organisms have symbiosis with other organisms that are constantly present in the ecosystem. Other times, when one of the symbiotic partners is a migratory animal, the symbiosis only occurs in certain seasons. Animals that migrate perform different roles in different ecosystems at different times of the year.

Find three examples of animals that migrate to, from, or through the ecosystems of Jones Beach.

Examples: Monarch Butterflies; Alewives; Green Darners; Snowy Owls; American Eels; Right Whales; Harbor Seals.

Ecosystems comprise more than just these relationships between organisms.

Nonliving parts of an ecosystem are called abiotic factors. These are all of the things that are present in an ecosystem, or characteristics of the ecosystem, that allow organisms to live within it. For instance, a rainforest is different from a desert because of abiotic factors, not just organisms.

Compare and contrast abiotic factors in three of the ecosystems of Jones Beach.

Examples: the brackish water of the salt marsh versus the freshwater (rain) of the pollinator garden; the sandy soil in the dunes versus the peat mud of the marsh; the relatively high winds on the beach versus shelter from wind behind the dunes and in the marsh.

Harbor Seal
Sean Hanley and G. Anthony Svatek

What makes a strong food web?

These various categories of organisms and environmental factors are all in ongoing exchange with one another. Each performs an essential function for the ongoing cycling of energy through an ecosystem. Primary producers bring energy into the ecosystem by generating chemical energy from sunlight. Primary consumers consolidate that chemical energy for consumers with higher energy needs. Secondary consumers keep the population of primary consumers under control so that the autotrophic base of the ecosystem can sustain itself. And lastly, detritivores and decomposers facilitate the cycling of essential nutrients so that the process of energy production and consumption can continue unhindered.

All of these functions are necessary, so a strong food web is one where each is operating in proportion to the others. A healthy ecosystem is also one where multiple organisms fulfill the same function or occupy the same "ecological niche," and each organism can derive energy from multiple others. Otherwise, the system is vulnerable to collapse if a single actor experiences a problem, like the introduction of a new predator or infection with a parasite or other disease. This characteristic is called biodiversity, and it's a key component in ecosystem resilience, which describes the ability of the ecosystem to "bounce back" from disturbances.

LEARN MORE

See 2.2 for discussion of relationships of interdependence within ecosystems, and 2.3 for discussion of resilience and adaptation, especially to the changing climate.

Energy, organisms, and eating

We only extract a portion of the energy and matter contained in what we consume. Waste is always a byproduct of eating and digestion, whether the excrement we expel from our bodies, or the parts of an organism that we don't eat, like bones, fur, roots, peels, pits, and stalks. The rest of the mass that we consume is assimilated into our bodies, where the chemical energy it contains may be used for different biological processes — including blood circulation, muscle movement, maintaining our internal body temperature, operating our nervous system, and digestion itself — or stored in fat and muscle cells. About 15 to 50 percent of plant matter and 60 to 90 percent of animal matter will be assimilated into the body of the feeding organism.

In any given food web, only 0.1-15 percent of the overall energy possessed by the bodies of the organisms that populate a given trophic level is transferred to the organisms in the trophic level above. (Trophic levels are groups of organisms at the same degree of remove from the primary source of energy in the ecosystem, the sun. Plants and other photosynthesizers are primary producers, while the animals that feed on them are primary consumers; the animals that feed on primary consumers are secondary consumers, and so on.) The rest is dissipated into the environment through respiration or fixed in matter that cannot be digested. Because so much energy is "lost" as it travels through the food web, the further removed a consumer is from the primary producer, the less energy is available to it within the ecosystem. This functions to keep the populations of organisms at different levels relatively stable, barring any major environmental disturbances: predators can't completely take over, because if their prey are not able to survive to reproduction, they will soon run out of food. This activity explores these dynamics through an interactive role play.

Monarch Butterfly on Goldenrod
Margaret Bourne

Part 1: Game play

Instructions for teachers

Have each student read their assigned character profile and determine which other species they interact with, either as a source of energy or as a predator.

Round 1: Assuming a class of 24 students, there are: 4 Abiotic Factors, 3 Cordgrass, 3 Seaside Goldenrod, 4 Monarch Butterfly, 6 Diamondback Terrapin, and 4 Great Egret. Play the scenario out for 5 minutes.

Round 2: Assuming a class of 24 students, there are: 4 Abiotic Factors, 7 Cordgrass, 7 Seaside Goldenrod, 2 Monarch Butterfly, 4 Diamondback Terrapin, and 2 Great Egret. Play the scenario out for 5 minutes.

Round 3: assuming a class of 24 students, there are: 4 Abiotic Factors, 3 Cordgrass, 3 Seaside Goldenrod, 6 Monarch Butterfly, 4 Diamondback Terrapin, and 2 Great Egret. Play the scenario out for 10 minutes.

Round 4: use the Round 3 as a baseline. Pesticide use wipes out half of the Primary Consumers (students sit out the round).

Round 5: use the Round 3 as a baseline. A housing development wipes out 3/4 of the Primary Producers and 1/2 of the Abiotic Factors (students sit out the round).

Materials

- **$4 in pennies, or 400 of another small object, like toothpicks or paperclips**
- **Pollen tickets: three sets of three same-colored tickets**
- **Nametags**
- **Plastic Cups**

For full activity materials, see:

Unit 2 Appendix Pages 4-6

Abiotic Factors

You provide solar energy, water, and nutrients. Your job is to distribute the building blocks of growth to the ecosystem's species.

Start with 300 pennies

Interactions

Primary Producer: Give 4 pennies.

Monarch Butterfly

You are a primary consumer. You obtain energy from primary producers. You are also a pollinator, so you can carry pollen between flowering plants (Seaside Goldenrod) to help them to reproduce and survive.

Start with 6 pennies, 0 pollen tickets.

Survive round with 12+ pennies.

Die during round by being eaten.

Interactions

Cordgrass: Take 2 pennies.

Goldenrod: Take 2 pennies, exchange one pollen ticket if available. (Only carry one ticket at a time.)

Secondary Consumer: Potential predation. Flip a penny. Heads means you are eaten. Give consumer 1/10 of your pennies and leave ecosystem.

Cordgrass

You are a primary producer. You transform solar energy into chemical energy through photosynthesis. Your seeds are spread by wind and water, so you do not need to be visited by pollinators in order to reproduce.

Start with 2 pennies.

Survive round with 4+ pennies.

Die during round by losing all pennies.

Interactions

Abiotic Factors: Take 4 pennies.

Primary Consumer: Give 2 pennies.

Secondary Consumer: Give 4 pennies.

Great Egret

You are a tertiary consumer. You are carnivorous, and obtain energy by preying on Primary Consumers (insects) or Secondary Consumers (sparrows and terrapin turtles). You are a predator: watch and wait.

Start with 20 pennies.

Survive round with 30+ pennies.

Interactions

Primary & Secondary Consumers: Potential predation. If prey has more than 10 pennies, flip a coin. Heads means predation is successful. Take 1/10 of prey's pennies.

Part 2: Debrief

As a group, discuss what can be gleaned from each round, and the game as a whole. Consider the following questions:

What happened in each round? What were the characteristics of a successful ecosystem? When did the ecosystem fail?

Why did different organisms need to have different amounts of energy by the end in order to survive?

Were energy, water, and nutrients distributed evenly? Was this realistic? In the real world, what would impact the distribution of abiotic factors?

In the predator-prey interactions, what does the coin-flip represent? Was this realistic? In the real world, what would impact the likelihood of successful predation?

What is left out in this game? Think about how different species use energy differently, and how some animals feed in groups.

How would reproduction and decomposition impact these dynamics?

Great Egret
Ian Sanderson

The carbon cycle, photosynthesis, and fuels

Under normal circumstances, the vast majority of the cellular matter produced through photosynthesis is digested or decomposed, its chemical energy transformed into heat or work by animal bodies. But in Earth's early history, during the Pennsylvanian and Carboniferous Periods, large amounts of this matter accumulated in swamps and laid undisturbed for millions of years. Under conditions of intense pressure and heat, this matter transformed into the coal, oil, and gas that humans now describe as "fossil fuels." When fossil fuels are burned to provide power to machines, the ensuing chemical reaction is a mirror of that which occurs during digestion and decomposition — but its impact on the environment is much different.

For full activity materials, see:

Unit 2 Appendix Page 7

Instructions

Read and analyze the linked resource to formulate answers to the following questions:

What is the carbon cycle? What is the chemical process of photosynthesis? What is the process of cellular respiration? What is the process of organic decay? What is the process of combustion?

How are hydrocarbons a part of the carbon cycle? What is the effect of fossil fuel combustion on this?

What does it mean to say that the carbon cycle is "fast" or "slow"?

Then, use the Internet to research answers to the following questions:

How does the chemical energy and combustion of fossil fuels relate to their origin as ancient photoautotrophs?

How are biofuels made from corn (ethanol) or algae similar to fossil fuels? How are they different?

What about these fuels makes them "sustainable"? In what ways are they "unsustainable"? What evidence and sources can back up these claims?

Source

NASA Earth Observatory | The Carbon Cycle

earthobservatory.nasa.gov/features/CarbonCycle

CORE CONCEPT 2

Energy drives interdependence in the ecosystem

Living beings within a natural system, including humans, depend on one another. Human activities can interrupt the flow of energy in an ecosystem.

Judy Gallagher

Energy in networks of dependence

In this Core Concept, the dunes south of the Jones Beach Energy & Nature Center frame an exploration of interdependence, biodiversity, and resilience in ecosystems. Interdependence is basic fact of all ecosystems that introduces vulnerability to environmental disturbances, while biodiversity is a characteristic that reduces this vulnerability and increases resilience. Although living beings in an ecosystem most fundamentally rely on one another for energy, interdependence includes many other kinds of relationships, as well as abiotic factors and the movement of elements like carbon, nitrogen, and water. Through the example of the dunes, students can see how phenomena like species migration and the mutualistic relationship between primary producers and (often migratory) pollinating primary consumers make local ecosystems dependent on the health of others thousands of miles away. Then, students explore the difference between natural disturbances and anthropogenic disturbances, brainstorming within different categories of human impacts and reasoning through the outsize effects of human developments.

Next, in a hands-on, small-group lab, students explore how human impacts produce knock-on effects that influence many more species than just those directly affected. Breaking links of interdependence can interrupt the flow of energy in an ecosystem, and a given ecosystem may be influenced by many different anthropogenic factors at once. Students exercise their critical thinking and analytical skills on fictionalized datasets and abstracts of scholarly research, interpreting data to draw conclusions, and formulating arguments based on scientific information. They also practice recognizing when existing data is insufficient, articulating data needs, and proposing scientific methods for gathering necessary data.

Lastly, a take-home reading response activity presents students with two different conceptual frameworks for understanding interdependence within ecosystems, and between ecosystems and human activities. Students are prompted to analyze, compare, and evaluate the frameworks, formulating a normative argument about how we can best engage with the natural world.

Michael Moran
Courtesy of nArchitects

Interdependence in the landscape

Observe the landscape of the secondary dunes and make notes of what you see. Consider the following questions:

How do different living things in this ecosystem depend on one another and the environment?

What interactions are occurring between species, between species and abiotic factors in the environment, and between different parts of the organisms themselves?

PRIMER

Give students a few minutes to respond, either alone or in small groups.

AT THE CENTER

Location: South Porch.

Groups working off site can use a nearby, familiar environment that includes plants and animals (like a lawn or a park) as their grounding example.

AT THE CENTER

Groups working with the curriculum on site can conduct the first portion of the discussion from the steps of the South Porch amphitheater, using the secondary dune ecosystem as a grounding example.

Groups working off site can use a nearby, familiar environment that includes plants and animals (like a lawn or a park) as their grounding example.

Interdependence, resilience, and human impacts

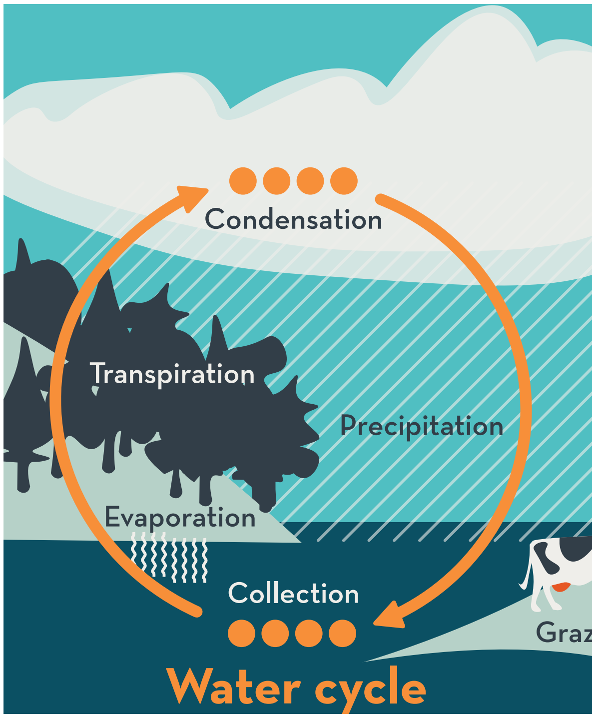
How do beings depend on one another on Jones Beach?

In the secondary dune ecosystem, a bird of prey like an Osprey may hunt small mammals and amphibians. But it also depends on the insects, mollusks, and smaller fish that their prey eat, and the bacteria, algae, and plants that those animals consume.

Organisms in an ecosystem don't only depend on each other for the flow of energy. Nesting animals rely on plants for shelter, and all organisms in an ecosystem rely on the abiotic environmental factors that make it habitable, like the soil, air, water, sunlight, and nutrients. They also rely on the organisms and abiotic factors that allow reproduction, whether pollinating species like bees and butterflies that service flowering plants, or the wind and water currents that spread seeds and eggs.

Interdependence describes a relationship in which each partner supports the function and survival of the other. This can be direct, as in the case of plant species and a pollinating species: Seaside Goldenrod depends on birds, bees, butterflies, and other insects to help it reproduce, and pollinators in turn rely on the plant for food in the form of nectar, seeds, or other plant matter. But interdependence can also be indirect. Consumers depend on producers, but producers also depend on consumers to reintroduce organic matter into the environment in the form of waste, and on decomposing bacteria and detritivore organisms, whoich break down organic matter into the component nutrients that producers use in photosynthesis, growth, and reproduction. Decomposition also releases heat energy into the environment, which is essential for organisms to maintain stable internal temperatures, keeping cells and molecules in motion inside the bodies of individuals.

Dependence in an ecosystem is better visualized as exchanges, networks, and cycles, rather than as flowing in a single direction. It is important to keep in mind the exchanges and cycles that are happening "behind the scenes" in a landscape, rather than focusing only on the chains of production and consumption that can be observed more directly.

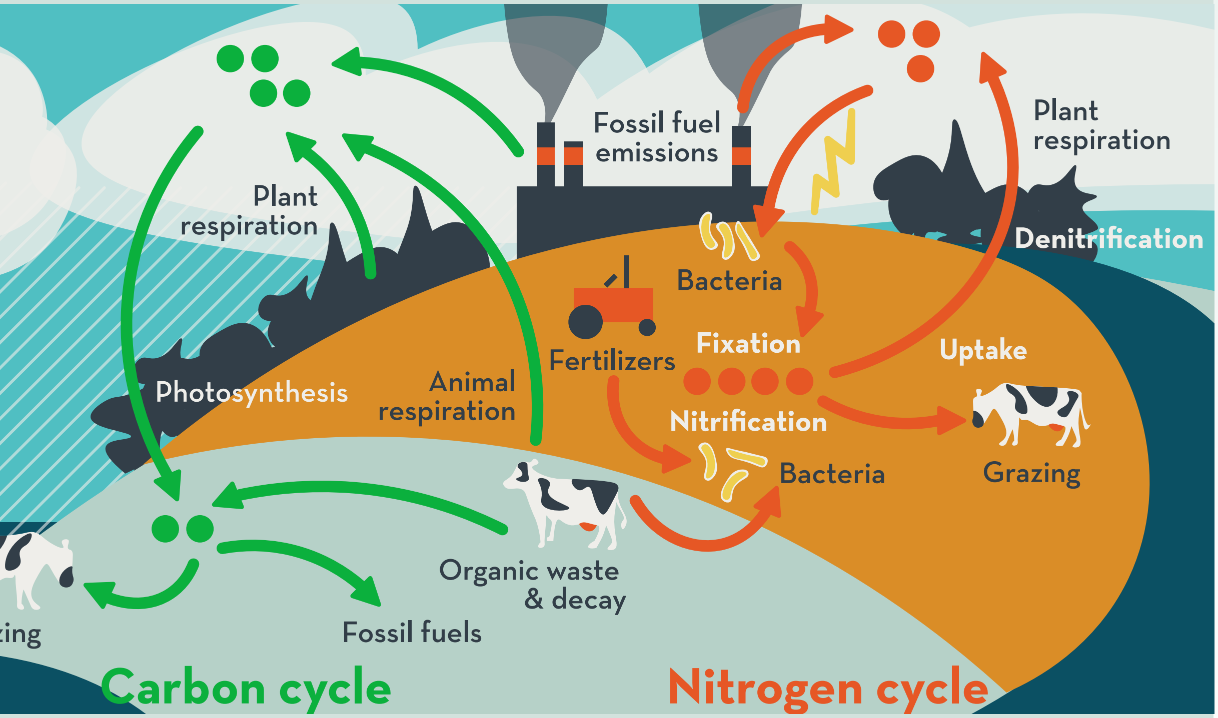


Cycling nutrients

Carbon is the building-block of all cellular lifeforms, used in the formation of the molecules that store chemical energy. In the carbon cycle, carbon flows between reservoirs: it is taken in by plants from soil and air, and by animals from plants and other animals, then released through respiration and decomposition before finally gathering in the atmosphere and in the soil, ready to be taken up again. Because there is a stable, finite amount of carbon in the universe, it is vitally important that this cycle continues so that organisms can continue to grow and reproduce.

Nitrogen is another essential building block for living beings, as it is used in the formation of proteins and nucleic acids — DNA and RNA — that enable growth and reproduction. Like carbon, there is a finite amount of nitrogen. Unlike carbon, nitrogen in its gaseous form cannot be absorbed by plants directly, so it must be integrated into the soil through a complex process of nitrogen fixation. 78 percent of the atmosphere is composed of nitrogen; in the nitrogen cycle, rain and lightning bring nitrogen to the soil from the atmosphere, where bacteria "fix" it in a form that plants can take up. Other organisms then obtain nitrogen by consuming plant matter; it returns to the environment in the form of organic waste and decomposing matter.

Water is another vital substance that cycles through the ecosystem. The water cycle is the result of the ongoing influence of energy on water molecules. Charged with more or less energy, molecules of water change physically, moving up or down, together or apart, depending on the state of the matter. Water passes through different places and roles in the ecosystem at different times.



REVIEW

LEARN MORE

See 2.1 for discussion of the food web, producer-consumer relationships, and trophic levels.

See 1.1 for discussion of how energy drives the water cycle and produces weather and climate.

What other cycles does the ecosystem depend on?

Another cycle impacting an ecosystem's survival is the seasonal cycling of various animals between different geographical locations, called migration. Pollinators perform a vital role in ecosystems like this one by allowing plants to reproduce, and many are migratory. For example, Monarch Butterflies and Green Darners "overwinter" in southern climates. Thus, flowering plants on Jones Beach, and all the organisms that depend on them, also depend on the health of the ecosystems where pollinators spend part of the year and on the pollinators' ability migrate from one place to the other. In the local marine ecosystems, many species that are food for other animals — like the Alewife, the American Eel, and the Horseshoe Crab — are also migratory, often moving to different locations in order to reproduce. If their migration is disrupted, or the ecosystem where they spawn is disrupted, the ecosystems of Jones Beach suffer.

Given all of this, what makes a healthy ecosystem?

Just because these cycles and exchanges are important doesn't mean they are inherently fragile. A healthy ecosystem does not necessarily stay the same all the time. Flux is an essential quality of all ecosystems: populations naturally wax and wane, temperatures rise and fall, and some years see more growth than others. Still, interdependence means that a disturbance affecting one species or environmental factor is likely to affect others. Natural disturbances like disease, infestation, wildfire, or flood can have a big impact. Resilience refers to an ecosystem's ability to bounce back from a disturbance and sustain the existence of species through flux. Because of the cyclical nature of environmental conditions and the long timescale of species evolution, ecosystems have generally evolved to be resilient to moderate natural disturbances. Sometimes a natural disturbance, like a flood or fire, is extreme and powerful enough to eliminate the existing species relationships; these disturbances, called succession events, allow new organisms to assert themselves. Over time, new relationships of interdependence develop.

Ecologists often measure ecosystem health by measuring biodiversity, which can mean both the number of species in existence within a given ecosystem and the genetic variation between members of a single species. Biodiversity means that more organisms are available to fill the same ecological niche, acting as a kind of insurance against species-specific disturbances like disease or predation. In the secondary dune ecosystem, there are several different producers and a variety of pollinators including small birds, bees, butterflies, and Green Darner dragonflies.

When do we have to worry about disturbances?

While ecosystems have adapted to withstand many natural disturbances, human activities can disturb ecosystems in ways that they have not evolved to handle. These are called "anthropogenic" or human impacts on ecosystems.

Humans can destroy the network of interdependence that allows energy to flow through an ecosystem by greatly reducing the population of, or even eliminating, any species in the food web. Overhunting and overfishing are significant ways that humans impact ecosystems, especially marine ecosystems.

Habitat destruction or disturbance also interrupts the network of interdependence. Constructing buildings or other structures on top of land destroys or disrupts habitats, and construction of infrastructure like roads, parking lots, or even streetlights, can disturb animals' natural patterns of movement. Using land for "natural" purposes like agriculture, or even certain kinds of gardening, can also cause habitat disturbance. But habitat disruptions need not be totally destructive in order to have an impact. For instance, the mere presence of human beings can deter birds like Piping Plovers from nesting and reproducing.

Another common example of human impact is pollution. This can come from industrial activities that produce chemical waste or release toxins into the environment. It can mean the proliferation of non-decomposing waste — like plastics in the ocean, garbage landfills, and nuclear waste — that is a result of our contemporary lifestyles. But pollution can also mean too much of usually positive nutrients, like nitrogen. Nutrient pollution occurs when human septic waste (excrement) or agricultural fertilizer introduce excess amounts of nitrogen into the water and soil, causing overgrowth of bacteria and algae that interrupts photosynthesis. In aquatic systems, this is called eutrophication and easily recognizable by the bright green blooms of algae that overgrow on the surface of the water due to the presence of excess nutrients. This overgrowth can prevent sunlight from reaching other organisms in the water, and distort the chemical balance in the water, threatening the survival of other species. The Great South Bay, north of Jones Beach, often struggles with nutrient pollution in part because many houses along the coast line are not connected to a sewer system and waste from the houses ends up in the water.

Note the connection between human population density or development and ecosystem disturbance: the more humans there are, the more food they need to produce through hunting and agriculture, the more land they take up for settlements, and the more waste they generate. Even in a world without plastics or industrial chemicals, this would still be an inevitable reality. Waste, in particular, requires ongoing management. How do the spatial distribution of human settlements and our current systems of managing waste and food production affect ecosystem health globally?

These impacts tend to be localized, or, in the case of some pollution, transported between ecosystems by wind and water currents. Meanwhile, climate change is a globalized human impact that affects all ecosystems on Earth in different ways and to varying degrees. In general, climate change amplifies natural disturbances like flooding, drought, and wildfire that ecosystems might otherwise experience to a lesser, more survivable degree. It also speeds up change processes that organisms might otherwise evolve alongside normally. Climate change also impacts ecosystems by changing where different species can survive, which allows the introduction of invasive species that may outcompete native species for limited food resources.

LEARN MORE

See 1.3, 2.3, and 5.3 for discussion of how climate change shapes ecosystems by driving sea level rise and changing weather patterns.

Dune fencing
Sean Hanley and G. Anthony Svatek

SPOTLIGHT

Good fences, good neighbors

The West End of Jones Beach is home to hundreds of species of animals that depend on particular environmental conditions found only on barrier islands like this one. Shore birds and shallows-dwelling marine animals, in particular, are at risk from the disturbances that threaten the dunes and tideline. Strong winds and waves may erode the land on which these ecosystems are built, while human impacts — from active habitat destruction to the mere presence of beach-goers — can prevent animals from feeding and nesting in the dunes and along the beach.

But conservationists can help protect these vulnerable ecosystems with a simple intervention: fencing. Snow fencing helps build up dunes by trapping sand as it blows and drifts along on wind and water currents. Meanwhile, native grasses help anchor the dunes with their root systems, further preventing erosion. Fences can also help protect animal species in the dunes and on the beach as they attempt to reproduce.

On the West End, volunteer stewards monitor Piping Plovers, erecting barriers around their nests so that they can lay and incubate their eggs without being disturbed. On other barrier islands, conservationists might use protective fencing to shield shore birds, Sea Turtles, Horseshoe Crabs, and other species during their mating season. The fences also protect eggs from potential predators, encouraging the population growth of Endangered or Threatened species.

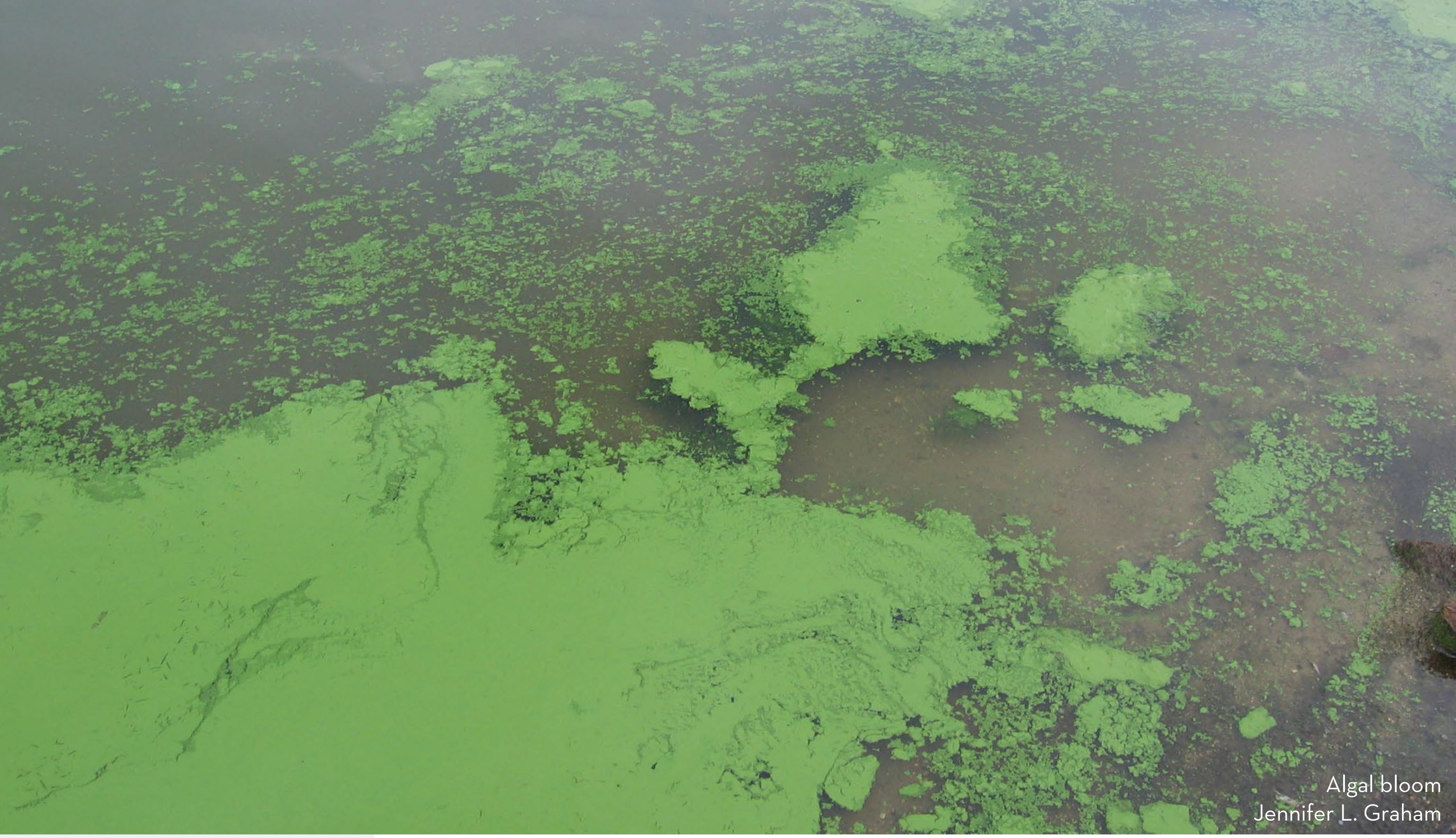
There are also positive human impacts. What are they?

Conservation is a general term for human activities that try to protect ecosystems from threats, anthropogenic and otherwise. The snow fencing that is visible from the South Porch at the Jones Beach Energy & Nature Center is one example: this human intervention helps the dunes withstand erosion due to strong winds and waves, which maintains habitat for the species that live in the dune ecosystem. Conservation can also entail data collection and monitoring the health of ecosystems. Each spring, during new and full moons, volunteers count, measure, and tag the horseshoe crabs that spawn in the surf at Jones Beach. Horseshoe crabs are a keystone species, so their reproduction impacts many other organisms.

The Pollinator Garden on the north side of the Center is an example of habitat restoration: a landscape design that creates new habitat where previously there was none, or where previous development had destroyed habitat. The ground underneath the Pollinator Garden was previously covered by an impervious concrete parking lot. By demolishing the parking lot and recycling the leftover concrete to construct the Garden, with new plants that support pollinators, the Center supports the health of many surrounding ecosystems.

Lastly, "remediation" is an intervention to attempt to reverse human impacts from past activities. This could include groups of citizens who collect plastics from the ocean or government agencies that clean up toxic chemicals released into the ground during industrial activities.

Barry Sloan



Algal bloom
Jennifer L. Graham

LEARN MORE

See 1.3 for discussion of the environmental impacts of energy use.

See Unit 5 for discussion of the environmental and social repercussions of climate change.

Note the connection between human population density or development and ecosystem disturbance. The more humans there are, the more food they need to produce through hunting and agriculture, the more land they take up for settlements, and the more waste they generate. Even in a world without plastics or industrial chemicals, this would still be an inevitable reality. Waste, in particular, requires ongoing management. How do the spatial distribution of human settlements and our current systems of managing waste and food production affect ecosystem health globally?

These impacts tend to be localized, or, in the case of some pollution, transported between ecosystems by wind and water currents. Meanwhile, climate change is a globalized human impact that affects all ecosystems on Earth in different ways and to varying degrees. In general, climate change amplifies natural disturbances like flooding, drought, and wildfire that ecosystems might otherwise experience to a lesser, more survivable degree. It also speeds up change processes that organisms might otherwise evolve alongside normally. Climate change also impacts ecosystems by changing where different species can survive, which allows the introduction of invasive species that may outcompete native species for limited food resources.

INVESTIGATION

Ecosystem detectives

Scenario

Citizen scientists have come to the New York State Department of Environmental Protection (DEP). with an alarming problem: In the last two years, their annual survey of Atlantic Blue Crabs in the Great South Bay has revealed a rapidly declining population. They fear that the crabs, a keystone species in the salt marsh ecosystem, are in danger of vanishing entirely.

Last week, the DEP called a meeting to try to get to the bottom of the matter. In attendance were councilors from the nearest town, Massapequa; representatives from the Long Island Blue Crab Fisheries Association; state fishery oversight officials; and the citizen scientists, who presented their findings. The meeting was inconclusive. State officials suggested that overfishing of crabs might have been to blame. Fisheries Association representatives argued that that was not the case, and that hard clams — a key source of food for the crabs — were being overfished instead. Or maybe the nearby town was responsible — residents' septic tanks have been known to overflow during storms. The councilors from Massapequa were offended at this suggestion. They argued that if pollution was to blame, the real culprit would be the cluster of autobody shops in the adjacent town, Amityville. The citizen scientists wondered if climate change might be to blame or if pesticides from nearby farms could be poisoning the water.

You are a group of investigators with the DEP. You must determine who is responsible for the declining population of Atlantic Blue Crabs. After the meeting, you collected what data you could from other citizen science efforts and government monitoring services about the conditions in the salt marsh, as well as a survey of the recent relevant research. You may draw a conclusion based on the data you have, or you have the option of running tests on water samples from three different sites around the marsh. (If you decide you want to “run tests,” just ask your teacher to give you the results.) If you determine that you do not have enough information to determine responsibility, instead determine what new data must be collected and propose a study design to obtain those results.

For full activity materials, see:

Unit 2 Appendix
Pages 8-13

Part 1: Investigation

Instructions

Review the resources in the data bank and discuss.

Interpret each data set and abstract. What do they tell you, and what don't they tell?

How do these different species and conditions relate to one another in the salt marsh? How are they vulnerable? What could be affecting each species?

Try diagramming a map of interdependence between species.

What do you hypothesize could be happening in the ecosystem, based on each data set?

Do any of the other data support or contradict these hypotheses?

Do you want to run tests on the sediment and water at these sites?

Materials

Scenario sheets

Site map

Initial data bank

Recent research abstracts

Water sample test results

Blue Crab census (surveyed annually, August 5)

Survey Year	Adult #	Juvenile #	Adult Avg. Length (mm)	Juvenile Avg. Length (mm)
2016	810	540	135	35
2017	872	563	131	34
2018	908	592	136	30
2019	760	350	128	34
2020	510	231	130	33

Abstract 2: "Hypoxia and acidification synergistically suppress growth, survival, and metamorphosis of marine bivalves."

Areas of low oxygen in coastal and open ocean ecosystems have grown in recent decades, and will continue to expand as the global climate warms. These low oxygen regions in the ocean are also acidified, containing larger quantities of carbon dioxide; as atmospheric carbon concentration increases, this condition intensifies. But little is known about how these dovetailing conditions affect sea life. This paper investigated the consequences of hypoxic (low oxygen) and acidified (high carbon) water on the development of young bivalves...

Hard Clam census (surveyed annually, July 25)

Survey Year	Number	Avg. Length (mm)
2016	1024	41
2017	996	36
2018	970	33
2019	902	26
2020	880	20

Part 2: Debrief

What did we find out?

What questions do we still have?

How would we go about investigating these questions?

If this trend continues, what do we predict would happen to the salt marsh ecosystem as a whole?

TAKE HOME: READING RESPONSE

Two frameworks for interdependence

Why should we value the health of an ecosystem? Do we evaluate the worth of an ecosystem based on how much it supports human life? Or is there something inherently worthwhile in the continued functioning of the complex and dynamic systems of life? These questions matter because they shape our decisions about which ecosystems to protect and what resources to devote to their protection. In the attached texts, two different authors propose two different ways of thinking about the value of ecosystems.

For full activity materials, see:

Unit 2 Appendix Pages 14-23

Instructions

Write a reading response summarizing, comparing, and evaluating the viewpoints presented in these two texts. Consider:

What is the "ecosystem goods and services" framework?

What is the "economy of abundance" framework?

What do you agree with or disagree with about each?

What are the strengths and weaknesses of each framework?

Which one feels more familiar?

Which one do you think is more valuable, and why?

What factors might contribute to either one being more common than the other in societal conversations about ecosystems and the environment?

Sources

Robin Wall Kimmerer, "The Serviceberry: An Economy of Abundance." *Emergence Magazine*. Published online, Dec. 10, 2020. Excerpted in Appendix and available in full online.

emergencemagazine.org/story/the-serviceberry

Thomas C. Brown, John C. Bergstrom, John B. Loomis, "Defining, Valuing and Providing Ecosystem Goods and Services." *Natural Resources Journal*. Volume 47 (2007) Page 329-376. Excerpted in Appendix and available in full online.

fs.fed.us/rm/value/docs/defining_valuing_providing_ecosystem_services.pdf

CORE CONCEPT 3

Energy shapes ecosystem conditions

Energy shapes the terrain of an ecosystem through the movement of air and water, while energy in the form of solar radiation drives the water cycle and increases global average temperatures, determining climate and sea level rise.

Sean Hanley and G. Anthony Svatek

Energy in earth, wind, and water

In this Core Concept, energy drives both local ecosystem conditions and world-wide climate patterns. First, in a guided, inquiry-based discussion, students explore how the terrain of Jones Beach is continually produced by energy in the form of wind patterns and ocean currents, as well as the solar radiation that drives temperature and precipitation patterns. Three examples of plants growing in different ecosystems around the island illustrate the role of consistent climate conditions in the evolution and survival of species. But long-term changes in climate and environmental conditions are also inevitable, and Jones Beach is also a prime example of how intermittent periods of glaciation, warming, and sea level rise shape terrain. Finally, students come to understand why anthropogenic climate change poses an extreme threat to ecosystems around the globe as it intensifies and accelerates the shifts in weather and terrain to which ecosystems might otherwise adapt.

In a small-group research activity, students use a variety of internet resources to explore different instances of the salt marsh ecosystem across the globe, investigating how they are shaped by their local climates and impacted by warming and sea level rise. Exercising investigative and data interpretation skills, students track similarities between the Jones Beach salt marsh and other marsh ecosystems. Lastly, a take-home reading response explains the phenomenon of ecosystem migration in response to sea level rise. Students interrogate the role of human development as a factor limiting systems' ability to adapt to climate change and use the provided guiding questions to analyze the common dynamics in each situation.

Eelgrass meadow under water at high tide
David Malmquist, courtesy of Virginia Institute of Marine Science

How does energy shape Jones Beach?

Besides the cycling of energy through the food web, how does energy shape Jones Beach?

Sean Hanley and G. Anthony Svatek

PRIMER

Give students a few minutes to respond, either alone or in small groups. Then move into the next activity by inviting students to share their answers.

AT THE CENTER

Groups working with the curriculum at the Center can begin by walking to the beach to observe energy in action at the tideline.

AT THE CENTER

Groups working with the curriculum on site can begin by viewing the Shaping the Shoreline exhibit in the South Gallery, the Wave Tank in the East Gallery, and the Wind Tunnel in the West Gallery.

Energy shapes ecosystem conditions

How does energy change the shape of Jones Beach over time?

All over the globe, the kinetic energies of water and wind move soil, rock, and sand around, literally shaping the land. Jones Beach is a barrier island, which means that it is particularly affected by the kinetic energy of wind and waves. A barrier island is a long sandy island that runs parallel to a shore — in this case, Long Island's South Shore. The terrain of the barrier island accumulates over time due to the action of waves, currents, and winds. Barrier island systems, usually chains of a islands along a coastline, protect the mainland shore from the impact of strong ocean waves, especially during storms.

Sand is deposited by currents and winds, gradually accumulating to form dunes and the beach. Along the South Shore of Long Island, dominant wind currents flow from the west and north, pushing dunes gradually towards the sea. Meanwhile, longshore currents flow parallel to the beach, pushing sand from east to west and moving the shoreline westward. Note that the construction of the jetty in the 1950s alters the shape of the West End of Jones Beach. The stone wall interrupts the flow of the longshore currents, causing sand to accumulate on the eastern side and keeping the channel to the west free of sand.

The shape of the shoreline changes seasonally, too. Winter and storm-season waves typically contain more energy, pulling sediment off the beach and into the water in a process called erosion. If large waves wash over dunes during high tides and storms — called "overtopping" — the dunes can flatten and shift. The dunes may then take years or even decades to recover through the gradual deposition of sand. Planting grasses and constructing sand fencing can prevent dunes from being washed away, and help encourage faster recovery after such events.

Other examples of the kinetic energy of water and wind shaping terrain might include rivers carving a riverbed or a canyon over time, heavy rainfall causing mudslides or other erosion events, or storms like tornadoes, cyclones, and hurricanes redistributing soil, rock, and water.

The movement of water and winds can also influence how species move through and between ecosystems. Birds, winged insects, fish, phytoplankton, and various other organisms travel on currents in the air and water, and currents also distribute seeds, eggs, and nutrients that organisms need to survive. Local examples of this include plankton that float on ocean currents, providing food for larger marine animals; shorebirds that depend on the strong sea breeze; and grass seeds spread by water and wind. Meanwhile, damage from major storms can decimate the populations of some species, impacting entire ecosystems.

Ruth Nervig

What other kinds of energy shape Jones Beach?

The same solar radiation that is the source of energy in the local food web also shapes an ecosystem by determining conditions like the temperature of the land, air, and water; the amount of precipitation and availability of water; the availability of light and cloud cover; and the strength and direction of wind — in other words, the weather.

Long-term trends in typical weather patterns are part of the local climate, helping to determine which organisms can survive in a given ecosystem and which ones perish.

Adrian Miller

REVIEW

LEARN MORE

See 1.1 for discussion of the role of solar energy in driving the circulation of water and air.

See 2.1 for discussion of the cycles, including the water cycle, that enable energy flow through ecosystems.

A map of the Köppen-Geiger climate classification system, showing the present climate as well as past and projected climate shifts, is available online:

koeppen-geiger.vu-wien.ac.at

Solar energy, convection, and climate

The sun heats the surface of the earth, causing molecules of water to expand and evaporate. In the atmosphere, the water cools and condenses, forming clouds of liquid droplets and ice crystals, depending on atmospheric temperature. As more water accumulates in the atmosphere, droplets and crystals are subject to gravity and pressure differentials between the sky and the ground; eventually, droplets and crystals fall to the ground as precipitation. The water flows across the surface in rivers and streams; collects in lakes, ponds, and oceans; and settles into the ground as groundwater and aquifers. Plants then take it up through their root systems and use it for growth.

Meanwhile, solar energy heats the air, but it does so unevenly, due to several factors including the angle of Earth on its axis and its uneven surface. Temperature differentials in different pockets of air create wind, as cool, high-pressure air moves towards warmer, lower-pressure areas.

What else determines the climate conditions in an ecosystem?

The latitude of a given place — its location relative to the equator — is one factor that affects how much solar radiation enters local ecosystems. Earth's tilted axis and yearly orbit of the sun mean that solar radiation hits different places on the planet's surface more or less directly at different times of the year. Altitude also plays a role in determining climate conditions, as oxygen and water — being material substances subject to gravity — are present in different amounts at different points of elevation and can absorb more or less solar radiation. A place higher up on a mountain might be less humid and colder than a place down in a valley or by a coast. In general, the warmer and more humid the climate, the more intense the patterns of evaporation, precipitation, and wind flow.

There are several systems for categorizing the different climates found throughout the world. One of the most widely used is the Köppen-Geiger climate classification system, which divides climates into five general categories: tropical, dry, temperate, continental, and polar. Within these categories, climates are differentiated further based on seasonal precipitation and temperature trends. Jones Beach, like the rest of Long Island and southern New York State, is categorized as a Hot-Summer Humid Continental Climate, which means that temperatures dip below freezing in winter, while the spring and summer include four months with an average temperature above 50°F and one with an average temperature above 70°F. Climates in this category also see no significant difference between seasons in the amount of precipitation. However, as global warming causes local climates to change, this and other climate categorizations are in flux. The changing climate has big implications for the hundreds of species that pass through Jones Beach or live here year-round.

Natural selection and species evolution

Species evolve and change over very long periods of time through the process of natural selection. Sexual reproduction allows for a variety of genetic traits within a species population, and some of those traits perform better than others in a given environment. Over tens of thousands of years, organisms with traits that are advantageous in certain environments are able to reproduce more, and gradually the genes that dictate those traits come to dominate the species gene pool. Sometimes, species within an environment coevolve, with mutually complementary traits that allow each to survive alongside the other within the local climate and environmental conditions.

How do climate conditions determine the kinds of organisms that can live in an ecosystem?

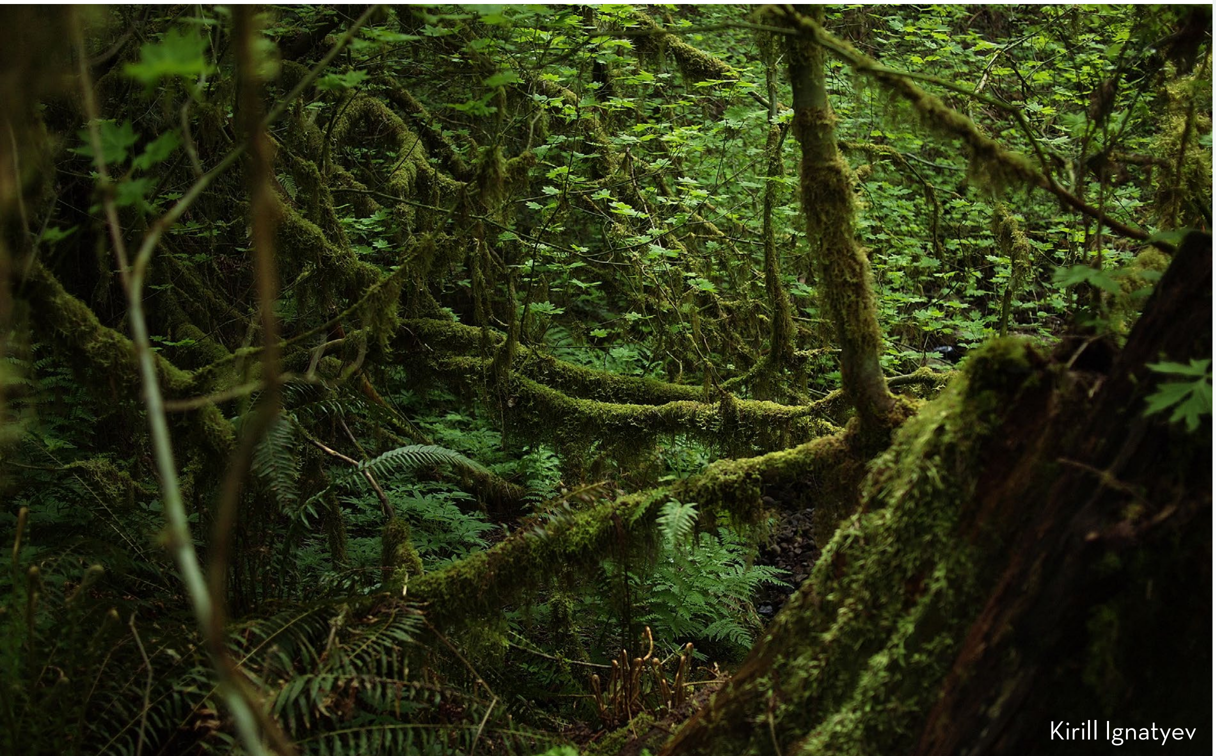
We can see the role of climate in determining species' survival by studying plants. Take some local examples.

The American Beachgrass that grows in the dunes here is adapted to the high-wind conditions of the beach. The roots grow out laterally, holding the sand in place and preventing the grass from being uprooted by wind.

The plantings in the rain garden outside of the Center are adapted to a certain average amount of rainfall.

The eelgrass that grows in the Great South Bay is adapted to a certain temperature, salinity, and nutrient balance in the water.

Other, global examples of ecosystems with particular climate conditions and organisms adapted to those conditions include cactuses in the desert, corals in tropical ocean waters, and ferns, mosses, and fungi on damp and low-light forest floors.



Kirill Ignatyev

There are many examples of ecosystem coevolution on Jones Beach, but the salt marsh ecosystem is particularly rich. Paleontologists believe that salt marshes have existed since the evolution of plants adapted to salt water conditions, approximately 425 million years ago. In the time since, millions of salt-marsh species — from microbes to mollusks, flowering plants to fish — have evolved to fit different ecological niches within the ecosystem.

Though organisms evolve to adapt to the terrain and climate conditions of their ecosystem, these conditions are not necessarily "supposed" to stay the same. In fact, over the course of Earth's history, climate and terrain have tended to change more than they stay the same.

What is the greenhouse effect and how does it relate to global climate change, ice melt, and sea level rise?

The build-up of carbon dioxide and other greenhouse gases in the atmosphere prevents long-wave thermal radiation from being released into outer space, and keeps energy from the sun (absorbed and then released as thermal radiation) inside Earth's atmosphere. This causes the global mean temperature to increase over time.

Over a million-year period, the amount of greenhouse gases emitted into the atmosphere is affected by many factors, including volcanic activity and the decomposition of dead plants and animals add greenhouse gases to the atmosphere. Meanwhile, the concentration of gases in the atmosphere may be reduced by the burial of organic matter through the deposition and reorganization of sediment, whether gradually or during sudden events like earthquakes, and the proliferation of photosynthesizers across the earth's surface. The changing concentration determines, in part, the amount of energy in the global climate system. As the atmosphere warms globally, ice melts and adds water to the oceans. Sea levels rise, and weather cycles intensify. Water expands as it warms, which on its own causes sea levels to rise.

But the rate and pattern of climatic change and sea level rise also vary across the globe, depending on the circulation of ocean and air currents. Feedback loops complicate and intensify these dynamics. Heat absorbed by water and land changes precipitation patterns and causes ice to melt, which in turn affects atmospheric and oceanic currents, which can in turn carry warm water and air to new places, triggering warming and cooling elsewhere.

At the million-year time scale, geological processes including tectonic plate movements can impact the direction and strength of these currents too. For instance, some geologists believe that when the land bridge between North and South America formed in what is now called Panama, it disrupted the flow of warm water between the Pacific and Atlantic Oceans and triggered the current Ice Age. Others argue that the rising of the Himalayan mountain range, due to tectonic plate collision, may have disrupted then-normal atmospheric currents and contributed to the cooling of the global climate.

Due to these dynamics, Earth has gone through cycles of warming and cooling repeatedly through the hundreds of millions of years of its history, with sea levels rising and falling accordingly.

LEARN MORE

See 1.3 for further discussion of greenhouse gases, and radiative forcing.

See 5.1 for discussion of feedback loops in the global climate system.

Video analysis

View the video that describes the formation of Long Island through glaciation.

What is visible in the video frame?

What is occurring globally and locally?

The video shows the formation of Long Island through the advancement and retreat of glaciers. As glaciers expanded in response to climate cooling, they deposited sediment in ridges called moraines, which gave Long Island its recognizable shape. Then, as the glaciers melted in response to warming, sea levels increased, carving out the coastline. Glacial meltwater was also left behind, forming lakes and the origins of the Great South Bay.

Globally, like the glaciers that are visible, glaciers elsewhere and polar ice may also be also melting. As global average temperatures increase, ice around the world melts, causing global sea level rise. It also freezes globally as the global temperature decreases, causing sea levels globally to drop.

BREAK OUT

AT THE CENTER

Groups working with the curriculum at the Center can watch the video as part of the Shaping the Shoreline exhibit in the South Gallery.

Melting ice in the Western Antarctic Peninsula
Maria Vernet

How does anthropogenic climate change shape ecosystems?

The difference between historical cycles of warming and cooling and the effects of anthropogenic climate change is a matter of timing, rate, and degree. Recall that "anthropogenic" — from the Greek *anthros*, meaning human, and *genus*, meaning origin — refers to the effects of human action. As discussed earlier, the greenhouse effect occurs naturally through the decomposition and geological processes, producing a historically normal pattern of warming and cooling. But in the last two centuries, human activities — specifically, deforestation and the burning of fossil fuels — have caused that rate to quickly accelerate, triggering what climate scientists call an "enhanced greenhouse effect."

This increased rate of warming has noticeable effects around the globe. The more solar or other heat energy there is in a system, the more frequently and intensely atmospheric cycles of evaporation and precipitation occur: anthropogenic climate change is tied to more intense seasonal storms and greater seasonal extremes of precipitation — both deluges and droughts. Warming also drives global ice-melt, which in turn drives sea level rise. Scientists have found that the oceans have absorbed more than 90 percent of the excess energy captured by the global system due to the anthropogenic greenhouse effect. As the global average temperature warms and polar sea ice and glaciers melt at an accelerated rate, global average sea levels are rising at a much faster rate than the normal historical trend.

Global sea level at the peak of the last interglacial warm cycle was 4 to 6 meters (13 to 20 feet) above the present level. That level could be reached again in the next several hundred years if ice continues to melt at its current rate. But these global trends might look different in different places at different times.

Map analysis

What is happening in this map, and why?

What do you notice about places where sea level is rising quickly?

Where is it rising slowly?

What could be contributing to these differences?

The map shows that sea level rise occurs at different rates in different places. This is due to the patterns of ocean and air currents, differing oceanic topography (the peaks and valleys of the ocean floor), and the gravitational pull of land masses on water. For instance, the sea level around melting polar sea ice actually decreases in some cases because the mass of the ice no longer exerts gravitational force on the water surrounding it. Conversely, sea level near cities may rise faster due to the gravitational pull from the mass of buildings.

Meanwhile, more frequent and more extreme weather events along the coast also cause flooding, as storm surge — the temporary sea level rise caused by a storm — can put land permanently underwater. This can make the shoreline more vulnerable to future floods and erosion.

Source

National Oceanic and Atmospheric Administration | Sea level trends

tidesandcurrents.noaa.gov/sltrends/sltrends.html

sea level trends , with arrows representing the direction and magnitude of change. Click on an arrow to access that station.

Relative Sea Level Trends

mm/yr (feet/century)

Above 9 (Above 3)	6 to 9 (2 to 3)	3 to 6 (1 to 2)	>0 to 3 (0 to 1)	-3 to 0 (-1 to 0)	-6 to -3 (-2 to -1)	-9 to -6 (-3 to -2)	Below -9 (Below -3)

Fire Island breach
Courtesy of United States Geological Survey

SPOTLIGHT

Storm surge, flooding, and the Long Island coastline

The combination of sea level rise and more intense weather due to climate change can have a particularly pronounced effect on barrier islands like Jones Beach. Global ice melt causes waters to rise gradually; though the change may be imperceptible from one day to the next, the rate of sea level rise has been accelerating in the last 25 years. Then, during seasonal storms intensified by the warming of the global climate system, higher waters are driven onto land by stronger winds, resulting in storm surge that can permanently alter the shoreline. Take Hurricane Sandy, for example: According to climate scientists, though the storm itself could not be conclusively linked to climate change, the extent and destructiveness of the storm surge flooding was a result of sea level rise due to global warming. The storm resulted in three "breaches" in the barrier island system along the southern coast of Long Island. If the breaches were left unaddressed, the shoreline on the north side of the Great South Bay would be more vulnerable to future flooding. However, breaches also play an important role in establishing and replenishing habitat for local species and increasing the spread of salt marshes, which themselves protect coastal settlements from the impact of storm waves. Ultimately, two of the breaches were closed, and one, in the Federal Wilderness on Fire Island National Seashore, was left open.

How does the rate of climate change affect resilience?

The ability of an ecosystem and its organisms to adapt to a changing climate depends on how quickly climate change occurs and whether the ecosystem is able to bounce back from sudden "environmental disruptions." The changing climate might manifest in gradually increasing or decreasing temperatures and amounts of precipitation. In contrast, disruptions are significant and often sudden events that are "abnormal" compared to the recent historical averages. Examples of disruptions due to climate change could be unusually strong storms, droughts, and floods. The ability to withstand disruption is called ecosystem resilience.

But a resilient ecosystem is not necessarily able to survive climate change if that change occurs too quickly or goes too far. Think about the earlier examples of American Beachgrass, Eelgrass, and the plantings in the rain garden. Imagine what happens if the winds and storms on the beach increase in strength or frequency, and if increased rainfall erodes the dunes? If the temperature of the water in the Great South Bay rises drastically? If precipitation levels in the rain garden change too much?

In all of these examples, we understand intuitively that some amount of change in these conditions is survivable. But beyond that threshold, changes to these conditions means that those organisms could no longer survive in their ecosystems. Too strong winds or too frequent storms could uproot the Beachgrass or prevent young plants from establishing themselves. Too much precipitation, too frequently, could drown the garden plantings, while too little or too infrequent rain could mean they don't have the water they need to grow. Eelgrass in particular is very sensitive to changes in water conditions. Human activity that accelerates climate change, then, threatens to push ecosystems past these thresholds faster and more suddenly than species can withstand.

As these species are threatened by the pace of change, other organisms that depend on them become vulnerable. Other species with advantageous traits — especially invasive species, which may be adapted for changing conditions, and which can compete with native species for resources — may be able to take advantage of their vulnerability. There are "winners" and "losers" in ecosystems impacted by climate change.

Even this is not unique in nature. In Earth's long history, species composition and environmental conditions have sometimes changed suddenly in response to events like volcanic eruptions, or, famously, the event that caused the dinosaurs' extinction. Ice Ages in particular have tended to begin suddenly. But the warming of the global climate has tended to occur more slowly, and its current relative speed means that human and ecosystem communities may not be able to adapt quickly enough to survive.

Sea level is rising especially quickly in New York and all along the East Coast, in part due to the subsidence, or gradual settling and compression, of the land. Water around Long Island, and in the Northwest Atlantic generally, is warming faster than the global average. On Jones Beach, we can observe the ongoing impact of anthropogenic climate change on complex ecosystems.

LEARN MORE

See 1.3, 5.1, and 5.3 for discussion of how climate change shapes ecosystems by driving sea level rise and changing weather patterns.

INVESTIGATION

Salt marshes near and far

Salt marshes, like the one to the north of the Jones Beach Energy & Nature Center, are ecosystems of vital importance across the globe. Commonly found in tidal estuaries, these coastal wetland ecosystems consist of beds of seagrass that are flooded and drained by the tide, with muddy soil containing large amounts of decomposing plant material. Salt marshes are a linchpin in the marine food web and are just as important to human food supply chains, as they provide food, shelter, and space for reproduction to more than 75 percent of commonly fished species. They also provide essential protection to coastal lands and communities by blunting the impact of storm waves and filtering stormwater runoff. Understanding the strengths and vulnerabilities of these unique ecosystems is key to the protection of the coastal environment.

For full activity materials, see:

Unit 2 Appendix
Pages 24-25

Instructions

Use the UN Environmental Program – World Conservation Monitoring Center's Ocean Data Viewer to explore the distribution of salt marsh ecosystems across the globe. Consider:

What do you notice about how this ecosystem is distributed?

Are there similarities?

What does the distribution suggest about the terrain and climate conditions of these ecosystems?

Pick one salt marsh to focus on. Zoom in so you can see the details of the shoreline but still have a good density of marsh in view. Use Google Earth and Google Maps to navigate to your chosen marsh. Zoom in to the same scale.

What do you notice?

What human developments are nearby? What other kinds of terrain do you notice nearby?

Use Earth: An animated map of global wind and weather to collect climate information about both your chosen marsh and the marsh on the northern side of Jones Beach.

Gather the following data points. Gather data for the current date; 3 months, 6 months, and 9 months ago; and the same dates over the last five years.

Temperature (Temp)

Wind Speed (Wind)

Relative humidity (RH)

Total 3-hour precipitation accumulation (3HPA)

Total cloud water (cloud cover) (TCW)

Air current direction

Ocean current direction

Using the Global Biodiversity Information Facility, navigate to and zoom in on the same marsh area. Explore the species occurrences listed in the marsh.

Try to find species that occupy the same niche in the ecosystem that the species below occupy in the Jones Beach salt marsh:

Great Egret (*Ardea alba*)

Saltmarsh Sparrow (*Ammospiza caudacuta*)

Monarch Butterfly (*Danaus plexippus*)

Eastern Mudsnail (*Ilyanassa obsoleta*)

Hard Clam (*Mercenaria mercenaria*)

Record both the common and Latin names of the species you find, if available.

Then, use Encyclopedia of Life to investigate these species further.

Where else can they be found?

Use Google search and Google Scholar to investigate these species. (Try searching the organism's Latin name.)

Is there any other information about their breeding, migration, or feeding habits would make them vulnerable to human impacts?

How are changing climate conditions likely to affect this species?

If there is sufficient class time, repeat the investigative process for another marsh system. Once you've gathered your data, discuss these questions as a group:

What is similar or different about the climate of the marsh(es) you investigated and that of the Jones Beach marsh?

What differences do you see between the species that populate these different ecosystems?

How do you think energy shapes these different ecosystems by determining climate conditions?

How do you expect that accelerated, anthropogenic climate change will impact these ecosystems?

Sources

UN Environmental Program | World Conservation Monitoring Center's Ocean Data Viewer

data.unep-wcmc.org

Google Earth

earth.google.com

Google Maps

maps.google.com

Global Biodiversity Information Facility

gbif.org

Encyclopedia of Life

eol.org

Earth: An animated map of global wind and weather

earth.nullschool.net

Note: Air and ocean current direction data is measured and reported in real time, but other data is drawn from various global climate modeling systems, i.e., it is forecasted rather than measured.

More information about these resources can be found here:

cleanet.org/resources/47829.html

Jones Beach salt marsh
Sean Hanley and G. Anthony Svatek

Invasive species, adaptation, and change

Ecosystems can become destabilized when "native" species — those that have originated in and adapted to a given habitat, with its distinctive climate conditions and terrain — are overtaken by invasive, nonnative species. *Phragmites australis* is a prime example of an invasive, nonnative species that has thrived in the tidal marshes of Long Island and the surrounding region in recent decades, at the expense of native species. But recent research has complicated the picture of *Phragmites* as an ecosystem villain, suggesting that *Phragmites* may be better suited to emerging climate conditions and better able to reduce the amount of carbon dioxide in the air, potentially limiting the effects of climate change. In this research activity, you must investigate *Phragmites australis* as a case study in nonnative species in a changing global climate system.

Instructions

Use the Internet to research *Phragmites australis*. Focus on the following questions:

What kind of plant is *Phragmites australis*? Where did it come from and how did it come to be in North America?

Why is *Phragmites australis* considered invasive? How does it spread and why is it hard to eradicate? What human impacts make marshes vulnerable to take-over by *Phragmites australis*?

What are the impacts of *Phragmites australis* on native marsh grass species? What are its impacts on other marsh species including fish, birds, and mollusks? Why is the spread of *Phragmites australis* a problem?

Then, read and analyze the attached scientific abstracts. The abstracts are written in technical, scientific language. It is not essential to understand every word. Focus on the following questions, and use the Internet to supplement with additional research as needed:

What question do the paper's authors set out to investigate? What is their method for investigating the question? What are their findings?

In what way is *Phragmites australis* well-adapted to the changing climate? Why is this significant?

What is "blue carbon"? How do nonnative marsh grasses including *Phragmites australis* strengthen the ability of coastal vegetated habitats to sequester atmospheric carbon?

In what way is the story of *Phragmites australis* an example of how energy shapes the ecosystem?

For full activity materials, see:

Unit 2
Appendix
Pages 26-28

Phragmites australis
Kerry Wixted

Sources

Abstracts excerpted in Appendix.

Davidson, IC, Cott, GM, Devaney, JL, Simkanin, C. "Differential effects of biological invasions on coastal blue carbon: A global review and meta-analysis." *Global Change Biology* 24: 5218– 5230. (2018). https://doi.org/10.1111/gcb.14426

Mozdzer TJ, Megonigal JP. "Jack-and-Master Trait Responses to Elevated CO2 and N: A Comparison of Native and Introduced *Phragmites australis*." *PLOS ONE* 7(10): e42794 (2012). https://doi.org/10.1371/journal.pone.0042794

BIBLIOGRAPHY • UNIT 2

Campbell, Gaylon S., and John M. Norman. *An introduction to environmental biophysics 2nd ed.* New York: Springer-Verlag, 1998.

Holling, C. S. "Resilience and Stability of Ecological Systems," *Annual Review of Ecology and Systematics*, Volume 4, 1973.

IPCC, 2021: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press. In Press.

Lindsey, Rebecca. "Climate Change: Global Sea Level," climate.gov, 2019. Webpage: climate.gov/news-features/understanding-climate/climate-change-global-sea-level

Newbold, Timothy, Hudson, Lawrence, et al. "Global effects of land use on local terrestrial biodiversity." *Nature* 520 (2015).

Odum, Eugene P. "Energetics." *Ecology: A bridge between science and society*. By Sunderland, MA: Sinauer, 1997.

Paine, R. T. "Food web complexity and species diversity," *The American Naturalist* 100.910 (1966).

Pimm, Stuart L. "The Structure of Foodwebs," *Theoretical Population Biology* 16 (1979).

Polis, G., M. E. Power, and G. E. Huxel. *Food webs at the landscape level.* Chicago: Univ. of Chicago Press, 2004.

Raymo, Maureen E. and Huybers, Peter. "Unlocking the Mysteries of the Ice Ages," *Nature* 451 (2008).

Smil, Vaclav. *General energetics: Energy in the biosphere and civilization*. New York: Wiley, 1991.

Strange, Elizabeth M. "Long Island's South Shore Barrier Island/Lagoon System." *Background Documents Supporting Climate Change Science Program Synthesis and Assessment Product 4.1: Coastal Elevations and Sensitivity to Sea Level Rise.* J.G. Titus and E.M. Strange (eds.). Washington, DC: US EPA, 2008.

Tanski, Jay. "Long Island's Dynamic South Shore: A Primer on the Forces and Trends Shaping Our Coast." New York, NY: New York Sea Grant, 2007.