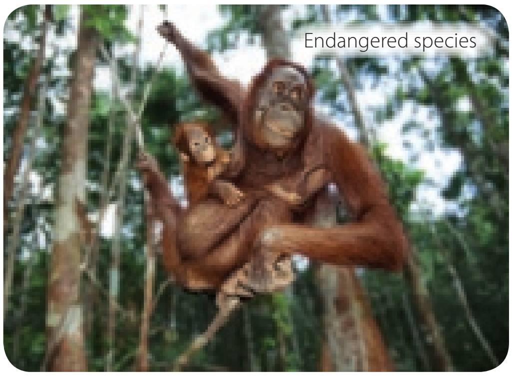
Core Knowledge® SCIENCE

Science Literacy

Ecosystem Dynamics:

How does changing an ecosystem affect what lives there?

Science Literacy Student Reader



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Ecosystem Dynamics

Science Literacy Student Reader

Core Knowledge®

ISBN: 978-1-68380-819-0

Ecosystem Dynamics

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Put Yourself in This Scene

The Stillwater Tribune

Letters to the Editor

To the Editor:

There's been a lot of discussion around town, including the recent open meeting with the board of supervisors, about what to do with Tillman Marsh, an 80-acre saltwater marsh that occupies about one quarter of our town's shoreline. As a descendant of Walter Tillman, for whom the marsh is named, I feel it necessary to point out that this marsh (and others like it) aren't just ecosystems that happen to exist in this region. They do things that are important for other systems, and they do things that are important for our species, *Homo sapiens*. Just a few examples:

- Tillman Marsh is home to many different fish, including winter flounder, striped bass, and bluefish, at one life stage or another. Without marshes, coastal and offshore waters would be deprived of sources of new generations of many fish. It's also home to many invertebrate species, such as blue crabs, fiddler crabs, snails, hard-shelled clams, soft-shelled clams, and whelks. Like their finned brethren, these species are vital to the local economy and regional marine economy.
- Great blue herons, egrets, ospreys, and even bald eagles depend on the marsh as a source of food. Bird-watchers and kayakers come to Stillwater because this marsh is a home to these birds. Those bird-watchers and kayakers often stop for doughnuts on the way into town and buy gasoline and lunch on the way out. Without the marsh as a draw to Stillwater, our local economy will suffer, especially in summertime.
- The marsh is a buffer and a sponge. It protects Stillwater from the brute force of tropical storm waves, and it soaks up pollutants. It is also a sponge for carbon.

Much has been made about the supposed economic benefits of flattening the marsh and replacing it with a shopping center, restaurants, and a condominium complex, but nobody seems to be giving the marsh any credit for the many benefits it has been giving Stillwater for two centuries—including millions of dollars in direct and indirect economic benefits.

Let's stop taking nature for granted. We need Tillman Marsh much more than we realize.

Thank you,

Dorothy Tillman

To the Editor:

I'm a third-generation fisherman here in Stillwater. My livelihood has depended on Tillman Marsh and other coastal wetlands both directly and indirectly. I dig steamer clams in the flats just outside the creek that flows through the marsh. I trawl for flounder and troll for bluefish in the summer, and I know these species use the marsh when they are young. When I see an osprey carrying a bluefish back to its nest in the middle of the marsh, while plankton-rich water moves in and out with the tide, I feel like I'm seeing the circle of life all in one view.

However, I can also see the writing on the wall. As a fisherman, I'm a rarity. The younger generation is not interested in fishing or making a living on the water. We need to diversify Stillwater's economy, and I don't think it's too much to ask to convert some of the marsh—no more than 50%—to the proposed development. Stores, restaurants, and a condo complex will add jobs and pump money into our struggling economy. What we are scratching out through a bit of fishing and ecotourism simply isn't enough. And I say that with a heavy heart, because I love what I do and I want my way of life to survive. But I think it has a better chance of surviving if the town has more going for it, including some well-regulated coastal development.

Regards,

Stu Moore

Both letters make good points and are written by people with strong ties to the community. One letter advocates for the conservation of the marsh, while the other endorses the idea of changing part of the marsh into a development. Who is right?

That's what this book is about—scientific literacy, which means knowing how to think about science topics that you read or hear about. Our world has 24–7 news, social media, and too may websites to count. The amount of information we must sort through is overwhelming, and all the information is not reliable. In the internet age, sources of information are often obscure or not trustworthy. It is good to process information with a healthy degree of skepticism. We will make our way back to the topic of replacing an ecosystem by the end of the book. Along the way, the series of reading selections and the writing exercises that go with them will help you flex your mental muscles and sharpen your science literacy skills. The ability to read about science, understand the information, and tell truth from fallacy or misrepresentation is important. Science literacy helps you as an individual and as a consumer, and it shapes the ways you affect the community in which you live.

Extracted Resources

Humans have figured out uses for many substances on Earth. This has affected the **ecosystem dynamics** where those substances are found.

Vocabulary

ecosystem dynamics, n. changes within the processes and system in a living environment

Logging is a form of resource extraction that affects forests directly by removing trees. Large-scale logging can involve heavy machinery and large trucks, which in turn means roads need to be made into the forest.

Boats race for position in Bristol Bay, Alaska, where millions of salmon are extracted. Seafood is a major source of protein for humans and livestock. Commercial fishing has had tremendous impacts on marine ecosystems.

Mushrooms are foraged from forests and other habitats. This is a relatively noninvasive form of resource extraction, because specific fungi are targeted and removed by hand. Even so, a part of the food web of the area is being removed.

Cacao beans are used to make chocolate. The cacao tree originated in South America, but it is now grown on plantations in tropical areas around the world. Depending on how a plantation is established and maintained, it can affect natural ecosystems.

Ecosystems have been affected by the extraction of animals. For example, the widescale removal of predator species, such as wolves from forests in the United States, has led to population booms among prey species, such as white-tailed deer.

Peat is a dense, carbon-rich substance that accumulates over time as plant matter decays. It can be dried and burned as a fuel or mixed into soil for agriculture and gardening. As you can see, extracting peat involves digging into peat bogs or fields. What does this do to this complex underground ecosystem?

One of the most abundant resources on Earth is water. Saltwater can be extracted from the sea to be turned into freshwater and salt. How does this affect the ocean ecosystem near shore?

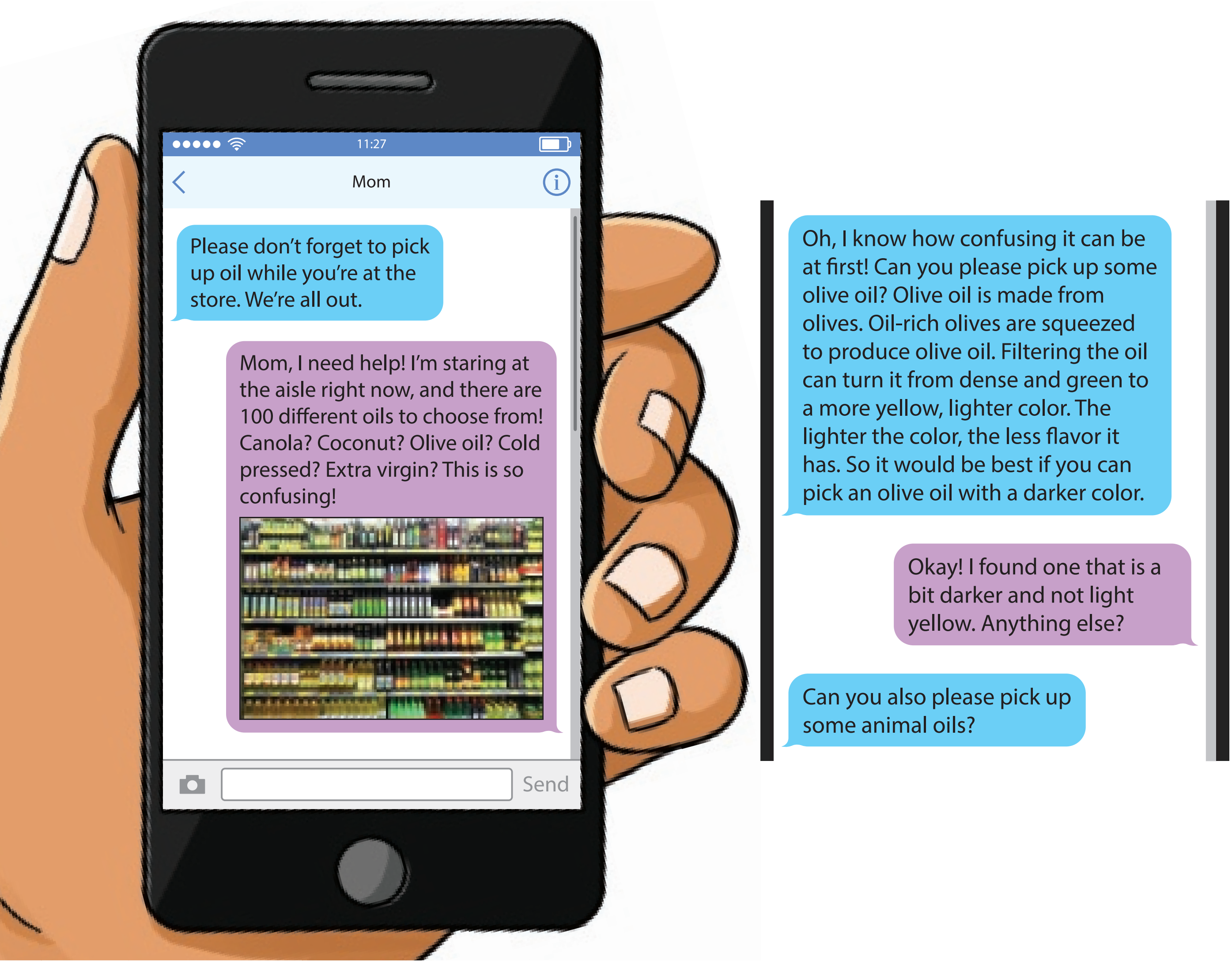
Humans also extract large amounts of nonliving material from Earth. In many cases, ecosystems are in the way of this type of resource extraction, and they are affected and often degraded by the machinery of industry.

Enormous amounts of petroleum and natural gas are extracted from Earth's crust. Setting up drilling and pumping machinery can take up space, shoving ecosystems out of the way. Accidents such as oil spills or platform explosions can wreak havoc on ecosystems, too.

Coal is another fuel that is extracted from Earth, often at great cost to ecosystems. In some cases, trees are cut down and mountaintops are blasted off to allow access to seams of coal underneath.

Marble and other types of stone are extracted from Earth. Such stones become building blocks, countertops, tables, floor tiles, and more. Ecosystems that are in the way of a potential stone quarry are often cut or bulldozed aside.

Shopping for Oils



SCIENCE IN HERE

Plant oils are produced primarily by squeezing the seeds of plants such as soybean, sunflower, canola, peanut, sesame, and olive. After most of the oil has been squeezed from a bunch of seeds, some still remains inside. This "cake" can be treated with heat and a chemical called hexane to draw out more of the seeds' oil. Some people prefer cold-pressed oils because there is less energy and fewer chemicals involved. The raw material that remains after the seed cake has been processed can be used as feed for livestock and farmed fish.

Huh???

Like duck fat or bacon. They would be in the refrigerated section of the store. Duck fat is a popular source of animal oil because it gives roasted or fried foods a rich flavor. But bacon is probably more well known. Either of those would work.

Okay, got some bacon because they didn't have duck fat.

Awesome. The last thing we need is some milk.

I see the milk. Do you want whole, 2%, 1%, or skim? What's the difference between these?

All dairy milk comes from cows and sometimes goats or sheep. The difference between whole, 2%, 1%, and skim has to do with how much fat is in the milk. But I'll fill you in on a little family non-secret . . . we don't drink cow's milk in our house! I've been buying nondairy milk for years. Normally we get almond milk or oat milk. Those are milks made from breaking down almonds or oats.

Wow, really? I guess I wasn't paying very much attention to the milk all this time! LOL I'm learning so much just from grocery shopping!

SCIENCE IN HERE

Some people raise or hunt animals specifically to extract fat and oil from them. It takes a lot of resources to raise these animals, such as water for them to drink, food for them to eat, and land for them to graze, thus affecting ecosystem dynamics. Using nonanimal sources of fats and oils, like coconut oil and nut-based milks, can help reduce the use of resources.

Connection

Fish oil is a nutritious product that some humans take as a dietary supplement. It is especially rich in omega-3 fatty acids, which are essential for functions of the heart, eyes, immune system, and lungs. Anchovies and krill—a shrimplike crustacean—are harvested and processed into fish oil. Omega-3 fatty acids can also be acquired by eating walnuts or flaxseed or oils made from them.

Once Hunted for Oil, Now an Ecotourism Draw

Scotland probably isn't on the top of most shark divers' bucket lists, nor is it known as a place for diving or swimming in general, with its chilly, soupy-green water. However, in summertime it is a destination for the basking shark, which is the second-largest fish in the world, and that means there is money to be made if you have a dive boat and can spot the large dorsal fins of these slow-moving, prehistoric-looking sharks.

Basking sharks feed on plankton—the stuff that makes the water here so green—and they do it by expanding their wide mouths and letting their massive gills strain the water until there's a mouthful of plankton to be swallowed. The sharks are harmless. They have no teeth with which to bite anything. They can be found in large groups, meaning it's possible to swim with a dozen different sharks in one outing.

It wasn't so long ago that this area was home to the world's largest basking shark fishery. In 1947, 250 sharks were landed in Scotland. Why? The basking shark's massive

liver, which can weigh 2,000 pounds, is loaded with an oil that was used for lighting lamps, lubricating machinery, fish oil for human consumption, and the production of cosmetics. This had a negative effect on ecosystem dynamics in Scotland. Toward the end of the 20th century, there was little market for the basking shark's liver oil because synthetic oils could be made at less expense. The death of the basking shark fishery helped protect basking sharks from overfishing, which in turn has allowed basking shark tourism to thrive here. It is a magical experience to swim with these gentle giants.

Squalene-Enhanced Skin Plumper

Some people demand flawless, ageless skin. Our new product, Squalene-Enhanced Skin Plumper, is the thing you and your face have been looking for! Made with 100% squalene, extracted from basking shark livers, this antiaging product will help your skin absorb all the nutrients, oils, and fats that it needs to decrease fine lines, sun spots, and other signs of early aging. Our patented formula guarantees to give your face a healthy glow after the first use! Don't fall for other brands that promise to give you immediate results at a premium price. We offer lower prices than competitor products that use unhealthy synthetic oils. Our products are free of chemicals, since we use all-natural ingredients that come directly from the sea. This makes it easier for us to offer you this skin plumper at an affordable price. ***Give our Squalene-Enhanced Skin Plumper a try today! Remember: natural is always better!***

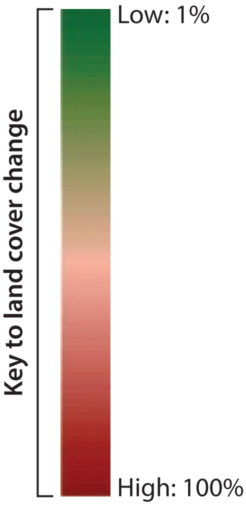
Spot the BS

Heads up! There is some **b**ad **s**cience on this page. This ad makes claims about its product. Can you detect which claims don't add up?

Land Cover Change in the U.S.

The landscape around the world is constantly changing. The United States Geological Survey (USGS) has a National Land Cover Database. This database captures the types of land cover in the United States. The USGS uses maps to turn the data into visuals, including visuals that display land cover change over time.

Land Cover Change 2001–2016



This map captures how land cover changed between 2001 and 2016. The greener the area, the less it changed. The reddest areas had near 100% change. Humans and climate are the biggest drivers of land cover change. Humans can cut down natural habitats, such as forests to build new neighborhoods, shopping centers, factories, highways, airports, and more. Climate change can cause a given area to become more or less livable for the organisms that make up habitats and ecosystems.

2016 Land Cover

Key to land cover types

- Open water
- Perennial ice and snow
- Developed, open space
- Developed, low intensity
- Developed, medium intensity
- Developed, high intensity
- Barren land
- Deciduous forest
- Evergreen forest
- Mixed forest
- Dwarf/Scrub
- Shrub/Scrub
- Grassland/Herbaceous
- Sedge/Herbaceous
- Moss
- Pasture/Hay
- Cultivated crops
- Woody wetlands
- Emergent herbaceous wetlands

This map shows the types of land cover as of 2016. Note the dominance of deciduous forest in the east, cultivated land in the Midwest, and scrub and evergreen forest in the west. California has a wide range of land covers, including evergreen forest in the north, scrub and desert in the south, dense urban areas along the coast, and the central valley where much of the United States' food is grown.

As humans continue to shape Earth's land and climate change impacts unfold as well, it is likely that we will see shifts in the ranges of some land cover types. For example, in the west, the evergreen forest could shrink as drought and wildfire take their toll.

From *The Log from the Sea of Cortez*

In 1940, the writer John Steinbeck traveled from Monterey, California, to Mexico on a sardine fishing boat called the *Western Flyer* to explore the Sea of Cortez, also known as the Gulf of California. Steinbeck was accompanied by a marine biologist named Ed Ricketts, and together they catalogued the many marine species they encountered on their six-week expedition. Steinbeck's narrative *The Log from the Sea of Cortez* was published in 1951. An excerpt is shared here.

April 8

In about an hour we came to the Japanese fishing fleet. There were six ships doing the actual dredging while a large mother ship of at least 10,000 tons stood farther offshore at anchor. The dredge boats themselves were large, 150 to 175 feet, probably about 600 tons. There were twelve boats in the combined fleet including the mother ship, and they were doing a very systematic job, not only of taking every shrimp from the bottom, but every other living thing as well. They cruised slowly along in echelon with overlapping dredges, literally scraping the bottom clean. Any animal which escaped must have been very fast indeed, for not even the sharks got away. Why the Mexican government should have permitted the complete destruction of a valuable food supply is one of those mysteries which have their ramifications possibly back in pockets it is not well to look into.

The cutting deck was forward, and the great dredge loads were dumped on this deck. Along one side there was a long cutting table where the shrimps were beheaded and dropped into a chute, whether to be immediately iced or canned, we do not know. But probably they were canned on the mother ship. The dredge was out when we came aboard, but soon the cable drums began to turn, bringing in the heavy purse-dredge. The big scraper closed like a sack as it came up, and finally it deposited many tons of animals on the deck—tons of shrimps, but also tons of fish of many varieties: sierras; pompano of several species; of the sharks, smooth-hounds and hammer-heads; eagle rays and butterfly rays; small tuna; catfish; puerco—tons of them. And there were bottom-samples with anemones and grass-like gorgonians. The sea bottom must have been scraped completely clean. The moment the net dropped open and spilled this mass of living things on the deck, the crew of Japanese went to work. Fish were thrown overboard *immediately, and only the shrimps kept. The sea was littered with dead fish, and the gulls swarmed about eating them. Nearly all the fish were in a dying condition, and only a few recovered.*

In addition to the shrimps, these boats kill and waste many hundred of tons of fish every day, a great deal of which is sorely needed for food. Perhaps the Ministry of Marine had not realized at that time that one of the good and strong food resources of Mexico was being depleted. If it has not already been done, catch limits should be imposed, and it should not be permitted that the region be so intensely combed. Among other things, the careful study of this area should be undertaken so that its potential could be understood and the catch maintained in balance with the supply. Then there might be shrimps available indefinitely. If this is not done, a very short time will see the end of the shrimp industry in Mexico.

Steinbeck and Ricketts encountered shrimp boats that netted thousands of pounds of shrimp, which was the target species, but also many tons of other, unwanted marine organisms. Bycatch remains a problem in many marine fisheries, especially those that use nets.

The History of Ecology

Vocabulary

ecology, n. the study of the relationship between living organisms and their environment

Centuries before other people showed much interest in studying biology, Greek philosopher Aristotle classified animals and studied their ecological relationships.

384–322 BCE, Aristotle

1735, Linnaeus's *Systema Naturae*

Swedish scientist Carl Linnaeus used multiple editions of his book to name and classify thousands of plants and animals based on common traits. His two-part naming system is still used in science today.

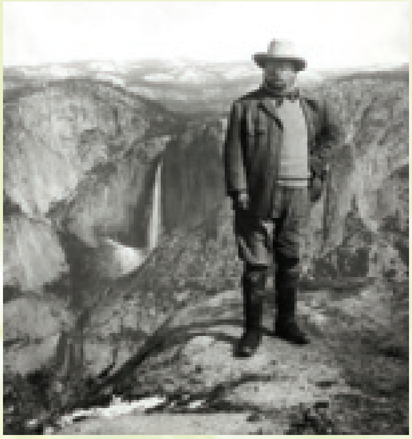
German scientist Alexander von Humboldt published a book summarizing his years of research in the connections between organisms, geography, and climate. His work inspired many others, including Charles Darwin.

1845–1862, Alexander von Humboldt's *Kosmos*

1859, Charles Darwin's *On the Origin of Species*

English scientist Charles Darwin spent years studying organisms and where and how they lived while developing a theory on how organisms evolved. His 1859 book was a major turning point in how humans thought about life, including the interconnectedness of different organisms.

The presidency of Theodore Roosevelt was marked by his commitment to conservation of nature. He used his authority to establish the national parks system, including the Grand Canyon and Yellowstone National Park.



1901, Teddy Roosevelt

1926, Charles Elton's *Animal Ecology*

Charles Elton studied the ecology of animals. His book examined connections between predator and prey populations, and he is credited with coining the term "food chain."

Eugene Odum wrote the first ecology textbook. His top-down approach to studying ecosystems laid the foundation for modern ecology and clarified the need to understand how different organisms share resources within systems.

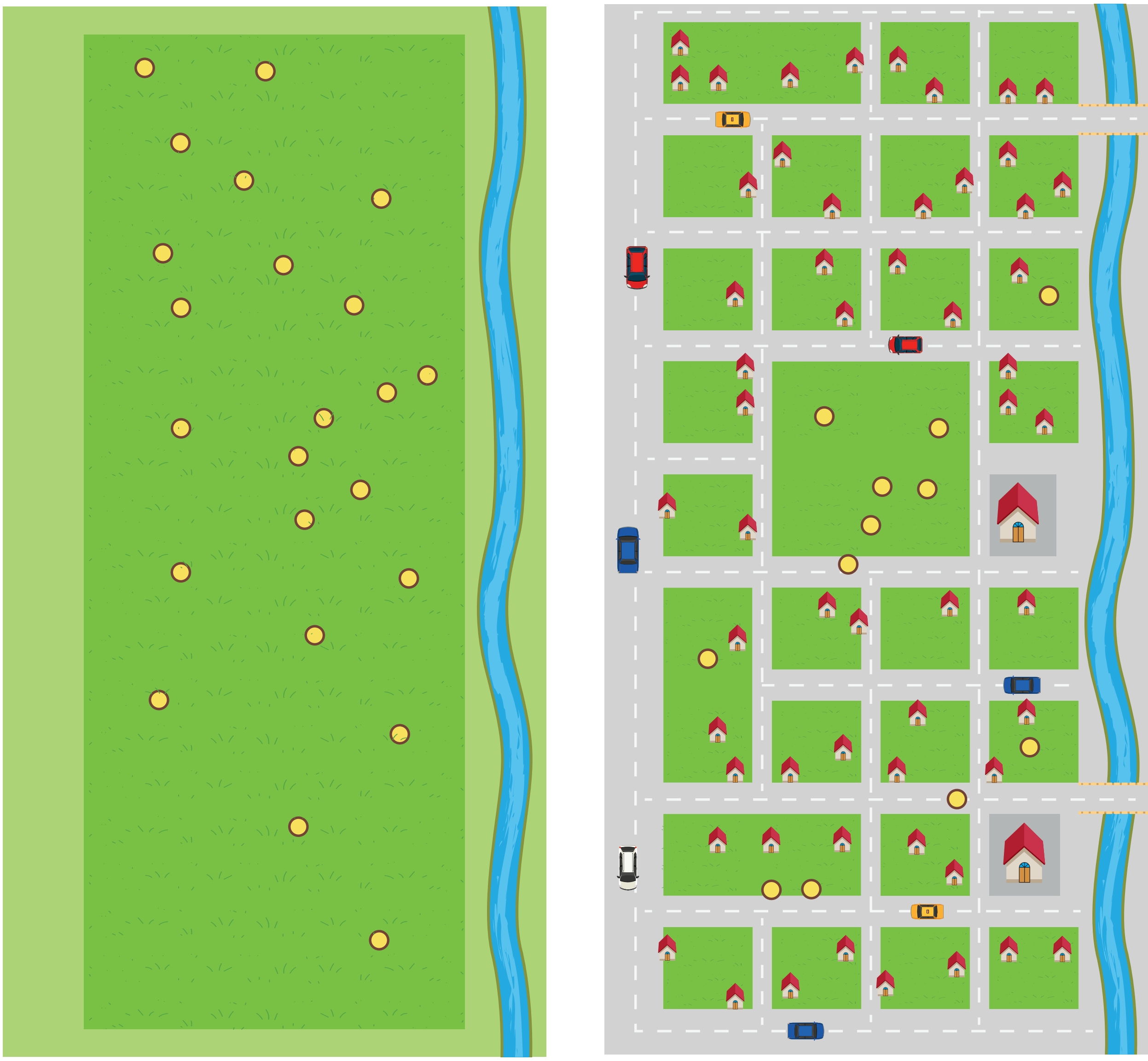
1953, Eugene Odum's *Fundamentals of Ecology*

1962, Rachel Carson's *Silent Spring*

Rachel Carson, a marine biologist, wrote *Silent Spring*, a book examining how chemical pesticides damaged organisms and ecosystems. Carson's work is often credited as the spark for grassroots environmental movements around the world. The pesticide DDT, used to kill mosquitoes, was banned in part due to Carson's advocacy and the public's response.

Habitat Fragmentation

When a habitat is broken up in into smaller fragments, that **habitat fragmentation** can disrupt how animals live, even if they have not lost too much habitat in terms of area.



On the left, the original forest habitat is represented by the large green rectangle, and the yellow dots represent deer. On the right, the habitat has become fragmented due to the development of homes and roadways. The overall area of the deer habitat has not declined by all that much. However, fragmentation means the deer that remain in this area are always near the exposed edges of the habitat, where they might feel less safe. The many gaps between the fragments mean traveling between them in search of food or shelter can be dangerous.

For small animals that do not move very far in their lifetimes, the fragmentation of habitat might not pose much of a problem. A slug, for example, may not be bothered if its habitat was divided by a new highway, because the range of the slug is so small that fragmentation barely matters. But what about the animals that eat slugs, or the animals that eat those animals?

In some areas, wildlife "corridors" are established to help migratory animals. Setting up conservation land so it has a shape that supports the migrating animals can help. For example, if animals are moving north and south from one season to another, it might make sense for conservation land to have long, uninterrupted stretches that run from north to south instead of east to west. What can be done to improve or add wildlife corridors to land that is already developed? Existing gaps can be bridged—literally—by connecting one fragment to another. Also, barriers can be knocked down. For example, a dam that blocks migrating salmon can be demolished.

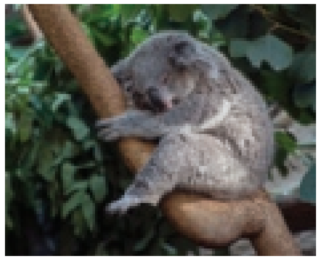
Vocabulary

habitat fragmentation, n. the breakup of a natural habitat into smaller pieces

This four-lane highway was a dangerous obstacle for migratory animals. Building an overpass that connects the two sides with a grassy, fenced path reduces the number of animals crossing the highway on the driving lanes.

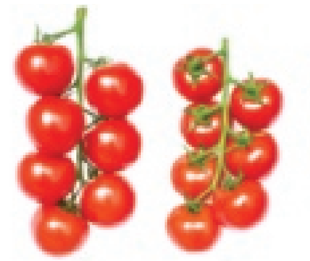
Native, Non-Native, and Invasive Species

Species can be described by whether or not they are native to a certain place and how they affect a new place after they arrive. The chart on these pages describes some animal and plant species in these terms. In many cases, the movements of species to new places is caused by human activity, either intentionally or not.

Name	**Cane toad, *Rhinella marina***	**Zebra mussel, *Dreissena polymorpha***	**Koala, *Phascolarctos cinereus***
Photo			
Native to	Native to Central and South America	Native to the Black Sea and Caspian Sea	Endemic to Australia
Invasive?	Highly invasive species in Australia, where the toad was introduced by sugarcane farmers to control insect populations that were eating the crop. The species is also now found in Florida.	Highly invasive species in freshwater bodies of water in the United States and other countries. It is thought that this species was brought from Europe to other countries in the ballast tanks of large ships.	Wild koalas are found only in Australia. They eat eucalyptus leaves, which are relatively low in energy. As a result, the koala sleeps up to 20 hours a day and moves at a slow pace.
Effect	Cane toads turned out to not be very good at controlling insect pests on sugarcane farms, but they were good at eating other insects as well as small mammals and even birds. They secrete toxic substances from glands on their backs and have poisoned many animals, including pets.	Zebra mussels outcompete native mussels for space. They also feed on phytoplankton and can outcompete zooplankton, resulting in depleted aquatic food chains. Zebra mussels also clog water intake pipes for lakeside power plants.	Koalas have been adversely affected by introduced species such as feral cats and dogs, as well as wildfire, habitat fragmentation, and being struck by automobiles.

Words to Know

An *endemic* species is native and found only in one place. An *invasive species* does harm to an ecosystem, often by outcompeting other species for resources or preying on native species. A *non-native species* may or may not be invasive.

Sugar maple, *Acer saccharum*	**Norway maple, *Acer platanoides***	**Tomato, *Solanum lycopersicum***
		
Native to eastern Canada and the United States	Native to Europe and western Asia	Native to Central and South America
The sugar maple is tapped to produce maple syrup. Its wood is used to make furniture, flooring, and musical instruments.	The Norway maple was introduced to the United States in the 18th century.	The tomato is often identified with Italian cuisine, but Italy did not have tomatoes until traders brought them to Europe from Central America in the 16th century.
The sugar maple's seedlings compete for space, nutrients, and sunlight with other seedlings, including the introduced Norway maple.	It is a popular shade tree in yards, but it can easily spread to nearby forests, where it outcompetes the sugar maple for space and soil nutrients. It is considered invasive for this reason.	Tomatoes are non-native on most continents, but they are not considered invasive. They tend to be grown almost exclusively in gardens, in greenhouses, and on farms, not in the wild. Their long, fragile vines tend to need support.

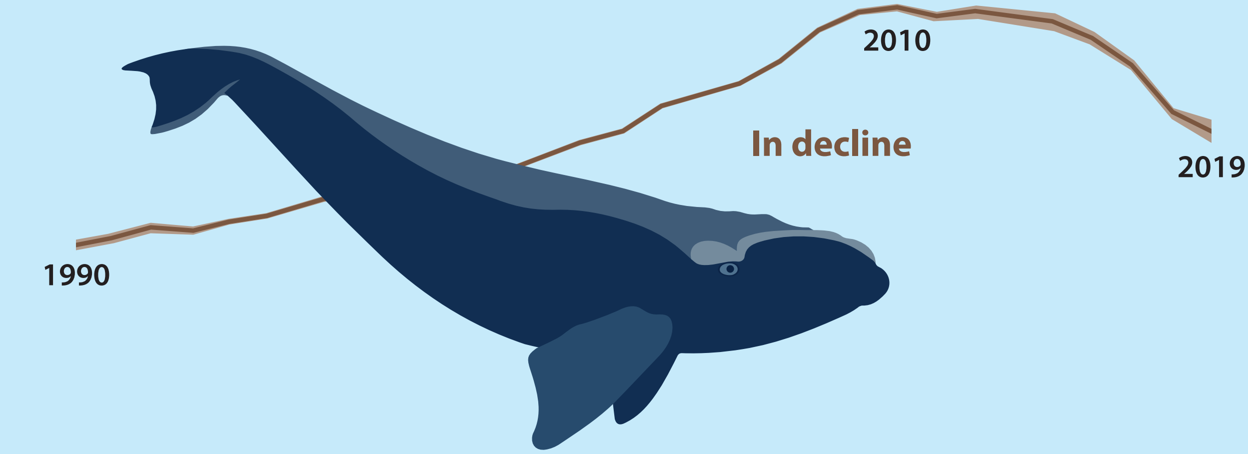
Right Whales, Wrong Place, Wrong Time

August 15, 2021

It's August in New England. Normally my team would be tracking North Atlantic right whales (NARWs) in the Gulf of Maine, which stretches from Cape Cod to Nova Scotia, as we've done for many years. In particular, we'd spend weeks in the Bay of Fundy, the northernmost part of the gulf. In the last few years, more NARWs have been showing up in the Gulf of St. Lawrence, well to the north. We don't know for sure what's driving the whales that way, but we think it's because their planktonic prey, the copepod *Calanus finmarchicus*, seem to be thriving in the Gulf of St. Lawrence and doing less well in the Gulf of Maine. And what's behind that? Most likely it's climate change.

The sad thing is that we had some success working with Maine's lobster fishers and shipping companies in the Gulf of Maine to reduce interactions between the whales and fishing gear and high-speed ships. Now, the whales are in other waters, where ship strikes and gear entanglements are happening perhaps even more frequently. NARWs got out of the frying pan and into the fire. In the Gulf of St. Lawrence, it's snow crab fishing gear that seems to be the cause of entanglements. Since 2017, we've counted 50 NARWs that have either died or suffered serious injuries, many of which were due to entanglements or ship strikes.

North Atlantic Right Whale



Only about **1/3** of right whale deaths are documented.

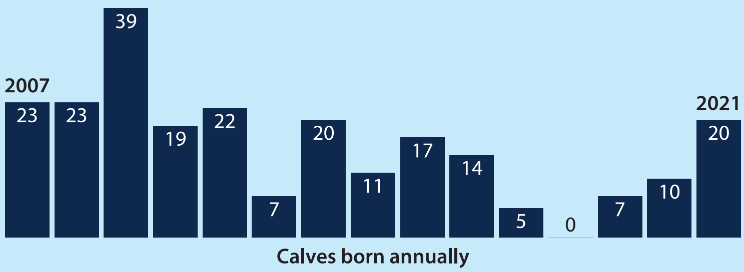
~368 Right whales left

50 Known dead or known serious injuries

34 Known dead

16 KSerious injuries

Only **42** new calves have been documented since 2017.



Dig into Data

Using the data in the chart, what can you predict about the population of right whales in the next 10 years?

School Study: Grasshopper Population

David Lopes, Sam Blanchard, Alicia Koester
Antelope Creek High School
Mrs. Roby's Biology Class

Introduction

The American bird grasshopper, *Schistocerca americana*, is common in grassy and forested habitats throughout Oklahoma except for the panhandle. It is orange-brown to reddish brown with dark spots on the forewings. White stripes on the forewings and head distinguish this species from other bird grasshoppers in the same genus. This species is an important prey item for egrets, mockingbirds, crows, and robins. We set out to estimate the end-of-summer population of *S. americana* in the meadow behind Antelope Creek High School.

Materials and Methods

We used stakes and string to mark off 100 square meters, what we call a quadrat. This would be our designated area to sample the population. We used butterfly nets and bare hands to capture grasshoppers that were found on stems, flowers, or leaves of meadow plants or were observed flying. Upon identifying a specimen of *S. americana*, we used a pink permanent marker to make a circular mark on the white stripe immediately behind the head. The number of specimens caught, marked, and returned uninjured to the habitat was recorded. All grasshoppers were released into the center of the sample quadrat. Twenty-four hours later, the same quadrat was sampled. This time, we counted the number of marked-recaptured specimens and the number of unmarked specimens, until we had a total number of captured *S. americana* that was greater than the total from Day 1. Again, all specimens were returned to the quadrat.

Results

The table captures the results of our mark-recapture study.

September 13	Specimens captured, marked, released uninjured: **57**	
September 14	Marked specimens recaptured: **13**	Unmarked specimens captured: **66**

We applied the Lincoln-Peterson Index to estimate the population size within the quadrat.

$$N = \frac{M \times S}{R}$$

N = population size estimate for the quadrat

M = marked individuals released, Day 1

S = total collected, Day 2

R = marked animals recaptured, Day 2

$$346.4 = \frac{57 \times 79}{13}$$

We applied our population estimate for the quadrat—346.4 per 100 square meters—to the overall area of the habitat, which we measured at 1260 square meters.

$$\frac{1260}{100} = \frac{P}{346.4} \quad P = 4{,}364.6$$

Our overall estimate for the population of *S. americana* in the Antelope Creek High School meadow is 4,365.

Discussion

Our population estimate was based on the ratio of marked grasshoppers and unmarked grasshoppers that we recaptured from a single quadrat. This quadrat represented less than 10% of the total area of the meadow. Using a second quadrat of the same size to increase the overall area sampled would make our estimate of the population more accurate.

We cannot be sure that predation of grasshoppers between Days 1 and 2 did not reduce the population. We also cannot rule out the possibility that marked grasshoppers were either more or less likely to be preyed upon by predators than unmarked individuals. It is possible that the pink marks attracted more attention from predators. It is also possible that the mark's aroma or taste could've repelled would-be predators. Marking the bellies of the grasshoppers might reduce the role that the marks themselves play in the predator-prey dynamics in the habitat.

The thousands of *S. americana* in the meadow represent an abundant food source for predators such as egrets and robins. They also represent a threat to the weedy plants in the meadow. If the habitat lacks grasshopper predators, the meadow could be decimated by an overly abundant grasshopper population. Next spring, we plan to join forces with another group in our class to estimate the number of grasshopper predators in the meadow while continuing our study of the *S. americana* population.

Word to Know

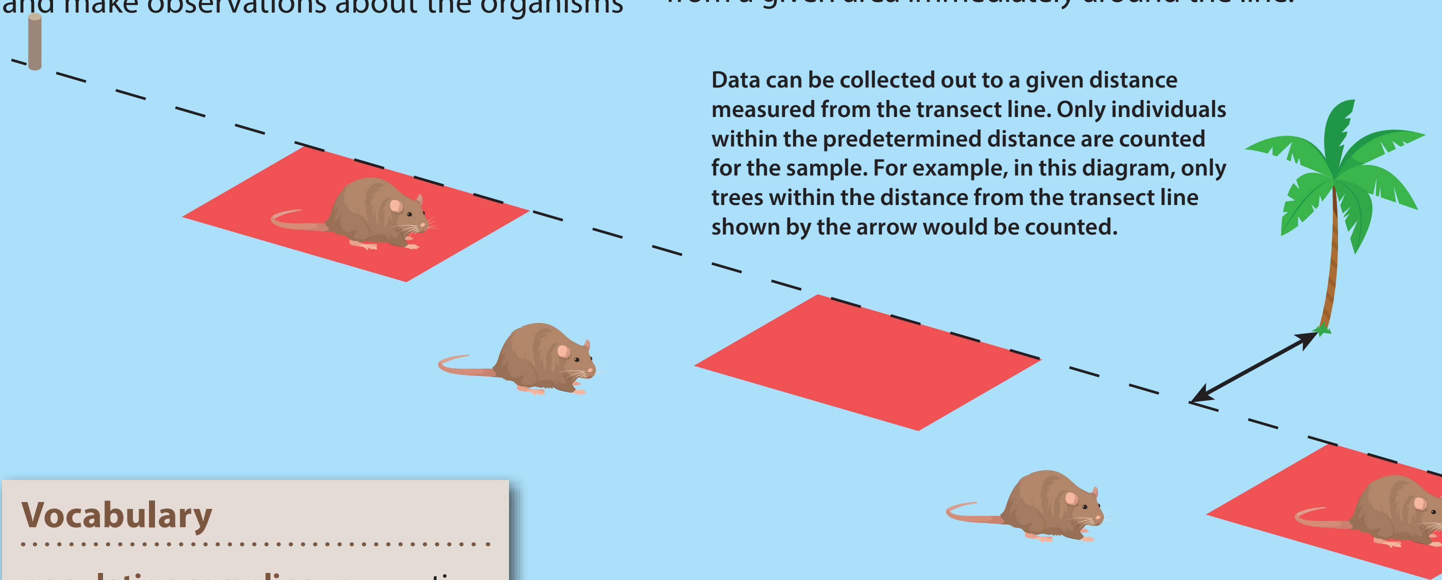
A *quadrat* is a shape that is either dropped onto a habitat (if it is a wooden frame) or marked using stakes and string. Organisms within the quadrat are identified. The data from the quadrat are then used to generate estimates about the larger habitat.

What Are Transects?

Population sizes for organisms in a given area are almost always estimates as opposed to exact, actual counts. Scientists use **population sampling** methods to count some individuals in an area and then develop broader estimates from the samples. In the grasshopper study, student scientists used a quadrat to estimate population size. An ecosystem or habitat also can be studied by using one or more transects. A transect is a line that is placed randomly across an area over a given length. Data collectors travel the length of the transect and make observations about the organisms that are found along its length and out to a predetermined width away from the line.

It's important for a transect to be placed randomly. If someone aims a transect so that it intersects with a certain type of tree or animal, then the estimates made based on the transect could be skewed. This would suggest that there are more of that organism in the habitat than there actually are.

Some transect lines are physically marked while larger ones can be studied by flying over an area in a straight line and making observations only from a given area immediately around the line.



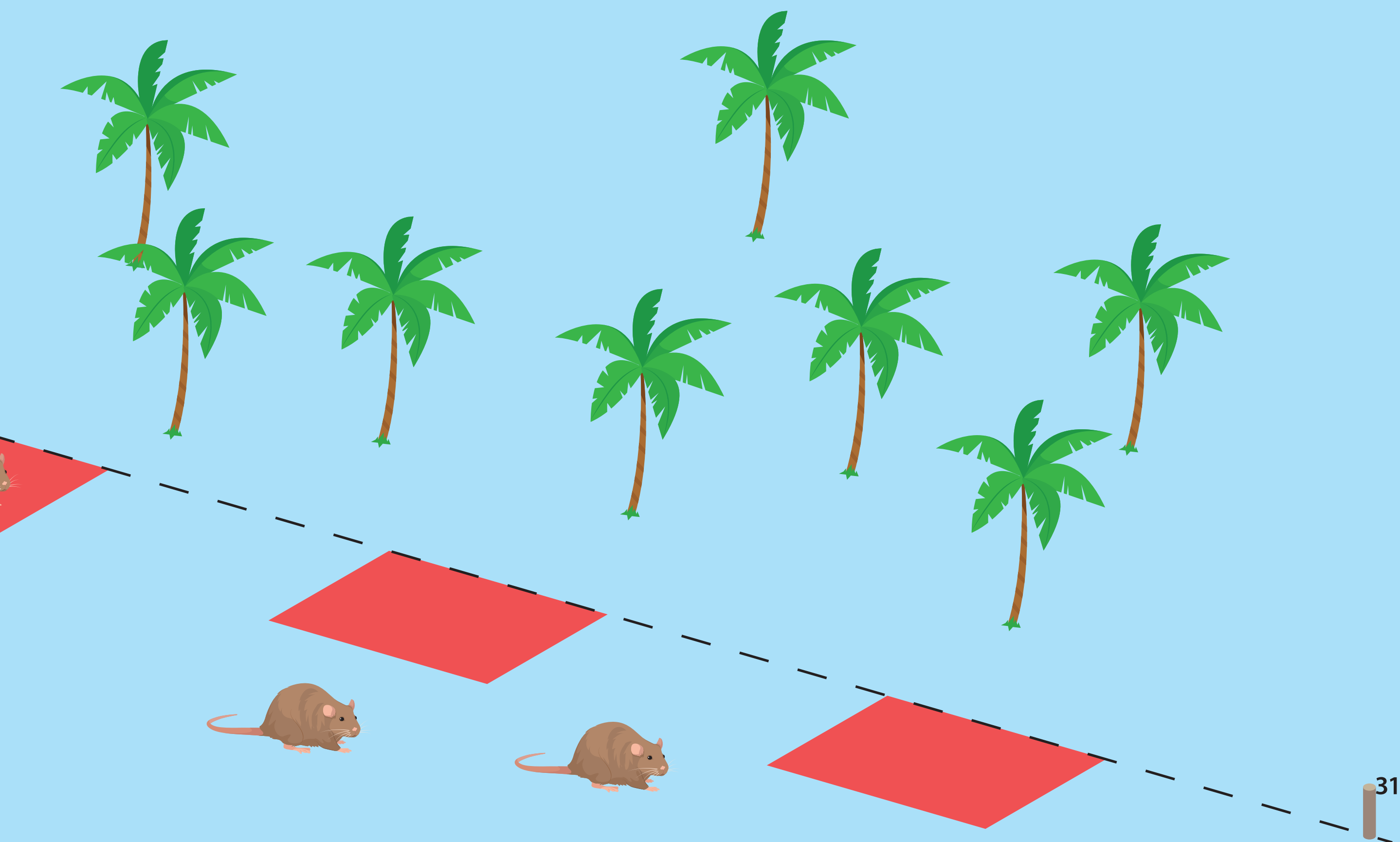
Data can be collected out to a given distance measured from the transect line. Only individuals within the predetermined distance are counted for the sample. For example, in this diagram, only trees within the distance from the transect line shown by the arrow would be counted.

Another approach is to sample quadrats along the length of the transect and then use math to generate estimates of population density based on the quadrat samples. For example, in this diagram, only the rats in the red areas would be counted.

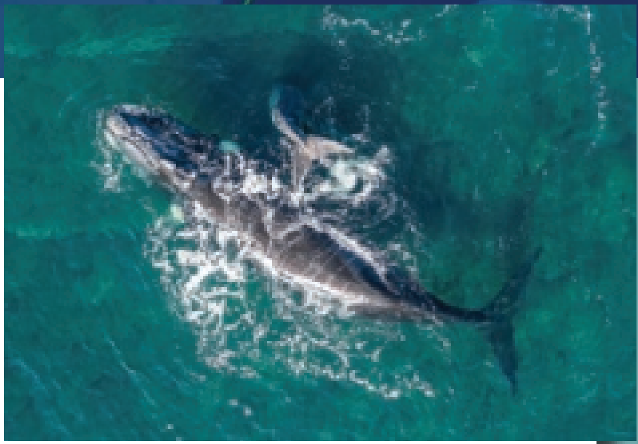
Vocabulary

population sampling, n. counting organisms within a small subset of an area in order to mathematically estimate the probable size of the whole population

In 1995, the biologist J. Michael Fay worked with a team to conduct a "mega transect" over 2,000 miles of the Congo Basin in Africa.



Counting Animals



Aerial Whale Survey

March 15, 2021

When I started flight school years ago, I didn't picture myself doing aerial surveys. Today I logged my 70th hour of this year's right whale survey. From our DHC-6 Twin Otter plane, we spotted another new mother-and-calf pair. The last few years have been very hard on the species, especially in summer when they're up north feeding among all that lobster- and crab-fishing gear. The two biologists I was flying out over the water off the Georgia coast were especially happy to see this new calf and its mom, who had not calved before. North Atlantic right whales, or NARW's as the biologists call them, are critically endangered. With fewer than 400 alive today, it's important that we know where they are and try to maintain an accurate count of their population.

The ocean's a big place, but because whales need to come to the surface to breathe, we can spot them from the air. The biologists take photos to find identifying marks on the whales. Once a new whale is identified, it gets a number and a code name. As the pilot on these surveys, my job is to fly in a pattern that allows us to survey a large area in the limited time we have in the air based on how much fuel the plane can carry. I fly a bit like someone mowing a lawn: I'll head five miles east, tack south, then fly back to the west, tack south, turn to the east, and so on. I also need to maintain an altitude that allows us to scan a wide span of water below but not so high that it's hard to spot whales.

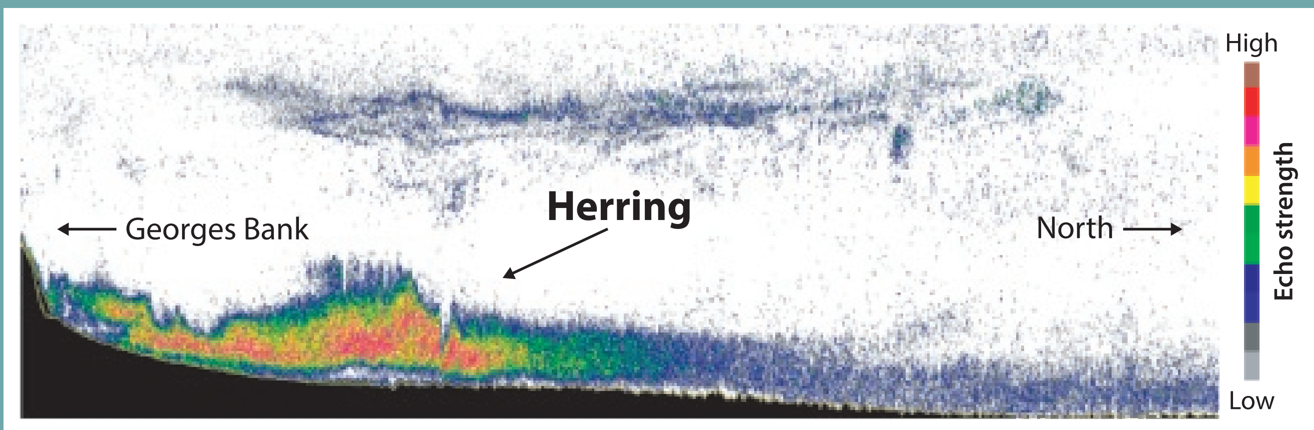
Surveying by Sonar

March 24, 2021

F/V Albatross

Fish populations can be estimated by dragging trawl nets through the water and counting or weighing what comes up in the nets. This is relatively easy to do in shallow water, but what about in thousands of feet of water? It's much more difficult to get nets down to those depths. Sonar gives us a tool to "see" what's down there without using light and without catching any fish at all. Sonar is a technology that sends sound waves out in a specific direction through water. When sound waves bounce back, or echo off objects, the way they bounce back can tell us what the object is like. We can visualize these echoes with echograms. For example, the echogram of the ocean floor looks different than that of a school of fish. A strong echo indicates a high-density school. A weak echo indicates lower density.

Some deep-water schools of herring are the size of skyscrapers. It's important to know how the herring population is doing because they are near the base of the food chain. The echogram here was produced during our survey yesterday, just north of Georges Bank, about 100 miles east of Cape Cod.



Science Interviews Podcast

Shark Niches Episode

(Begin transcript)

(intro theme music)

Jillian: Ladies and gentlemen, I'm Jillian, and I want to thank you, as always, for listening to my science podcast. I've got a very special guest in the studio today. I'm pleased to bring you a conversation with an intern at the Mote Marine Laboratory. She's been helping the lab with its annual shark tagging tournament. Shana, welcome to our show.

Shana: Thanks so much, Jillian. I'm pleased to be here.

Jillian: So, first, can you please tell us what the annual shark tagging tournament is? I mean, it almost sounds like a game where people compete for a big metal cup.

Shana: (laughing) Not quite. For a week, local recreational shark fishers register for this tournament, and they head out into the bay to fish for sharks.

Jillian: But this isn't *sport* fishing for sharks, right?

Shana: Not at all. This is all in the name of science and research. Fishing for the sharks allows us to tag them so we can track their whereabouts and behaviors over time. The lab puts an intern, like me, on each boat with the fishers. We help tag the sharks, and then back into the water they go.

Jillian: Do you have a particular area of interest as it relates to sharks?

Shana: I focus my studies on shark diets. Different species of sharks eat different things. And the age of the shark can impact its diet, too. Diet helps define an animal's niche. A niche is an organism's place and role in an ecosystem.

Jillian: Niche . . . meaning, the things about that species that make it kind of unique?

Shana: Right. For example, if the blacktip shark ate the exact same things as the bonnethead shark, they'd be competing head-to-head for the same resources. If there's plenty of that resource to go around, that could work out. But if not, one species might outcompete the other, and the other would either die out, need to move somewhere else, or need to find something else to eat. So, in general, most species have a niche that is somewhat their own.

Jillian: That makes sense. So, in the wild, what does the blacktip eat? And the bonnethead?

Shana: I've picked through the stomach contents from hundreds of each. Bonnetheads love crabs. The bonnethead has this broad face that scans the bottom using sensitive organs that pick up vibrations from prey. Crabs scurrying along the bottom or just sitting quietly in a clump of algae can be detected. I find quite a bit of algae in bonnethead stomachs. Most likely the algae is getting eaten incidentally.

Jillian: Sort of like the zucchini that my husband sneaks into the baked goods he makes?

Shana: Ha ha, yeah. Pretty much. Blacktip sharks don't seem to target crabs at all. I find a lot of small bony fish such as grunts and jacks in blacktip stomachs. Blacktips can get big, too, so as they grow, they go after bigger fish. Every once in a while, one bites a swimmer whose hand or foot reflects some sunlight and looks too much like a fish to pass up. But usually the bite is quick and not too damaging. They're not looking to eat people.

Jillian: Well, that's a relief! So, if someone wants to catch a big blacktip and maybe avoid catching bonnetheads, they could use a whole grunt or maybe a mullet for bait?

Shana: Perhaps. But a bonnethead that finds a dead fish hanging in the water might not pass up that free meal. If an animal can eat something, it probably will, especially if the meal is right there for the taking with minimal work or risk involved.

Jillian: Hey, that's how I like my meals, too! Shana, I can't thank you enough for speaking with us today. I hope you'll join us again.

Shana: The pleasure was all mine, Jillian. Love your podcast. Keep spreading the science news!

(Closing theme music)

(End transcript)

Leave Nature Alone

KCW **KC Wren**

After my morning yoga class, I took a long walk on the beach in Santa Monica. I had my green juice in hand and was feeling like I was in a meditative trance as I listened to the sounds of nature. I was walking by the pier and saw a bunch of fishing lines in the water. Well, then I saw a small crowd gathered around something long and gray. I went to get a closer look (big mistake) and found out that it was a beached great white shark! I had never ever seen a beached animal before, and let's just say I was no longer in a state of post-yoga dream. It was completely awful. I realize that this area is known to be a kind of nursery ground for white sharks. I have surfer friends who see baby great whites swimming around them off Malibu.

But what in the world is going on that caused this shark to be beached? I couldn't help but wonder if it had been caught and exhausted by someone fishing from the pier or if it had simply starved due to overfishing. It is hard not to think that humans are simply too numerous, too hungry, too predatory—or careless—in how we treat the other organisms with which we share this Earth. We need to get out of the way. There are too many fishing lines, oil rigs, noisy ships, and other threats to nature in the coastal waters of SoCal. Stop fishing and harming innocent marine animals!

Spot the BS

Heads up! There's some **b**ad **s**cience on this page. Can you see where the writer is leaping to conclusions about what they observed on the beach?

Most recent comments

I couldn't agree more. I run along the pier almost daily and see so many fishers out there. It's hard to believe that all of those fishing lines aren't getting in the way of the young sharks that swim around there. There should be laws that limit the number of fishing lines in a single area at the same time, to reduce the risk of sharks getting tangled up in the lines.

While it's terrible about the beached great white shark, it's hard to know for sure what causes these types of events. Yes, we as humans have done our fair share to interrupt or disrupt nature and the animals that inhabit our land and water. But I'm not sure we should jump to the conclusion that fishing is the main problem here. There can be natural causes at play, too. For instance, I've read that, like all creatures, sharks can get sick and know when it's their time to rest and let nature take its course. They might beach themselves when they no longer feel like they can keep up in the water. Also, whales sometimes beach themselves as a way to escape from shark attacks. So I don't think it's fair to assume that every instance of a beached marine animal is caused by reckless human activities.

I've seen one beached whale in my life, and it has scarred me ever since. I now volunteer to help spread information about noise pollution caused by cargo ships, cruise ships, etc. and get new laws passed to reduce human interference with marine life.

I am a wildlife journalist and have been researching and reporting on animals for the past 12 years. I can say with full confidence that humans are not the cause for every beached animal. Someone already mentioned that sometimes sharks or whales beach themselves because they get sick or are trying to escape something worse in the ocean. But animals also beach themselves when they are injured. Tidal patterns can become deceptive, which can confuse the animals and cause them to end up on beaches accidentally. Sometimes animals die in the waters, and the winds and waves drift their limp bodies to shore. It might appear that they died because of the beaching, but really they died prior to it. Other times, the topography of the ocean floor changes, causing a large animal to be stuck near the shore and unable to move on its own. Human activities are part of the problem but not the only part.

Consider the Sources

Of the four people who commented on this post, who constructs theories primarily from observations of personal experience? And who provides science-backed documentation for their reasoning and explanation?

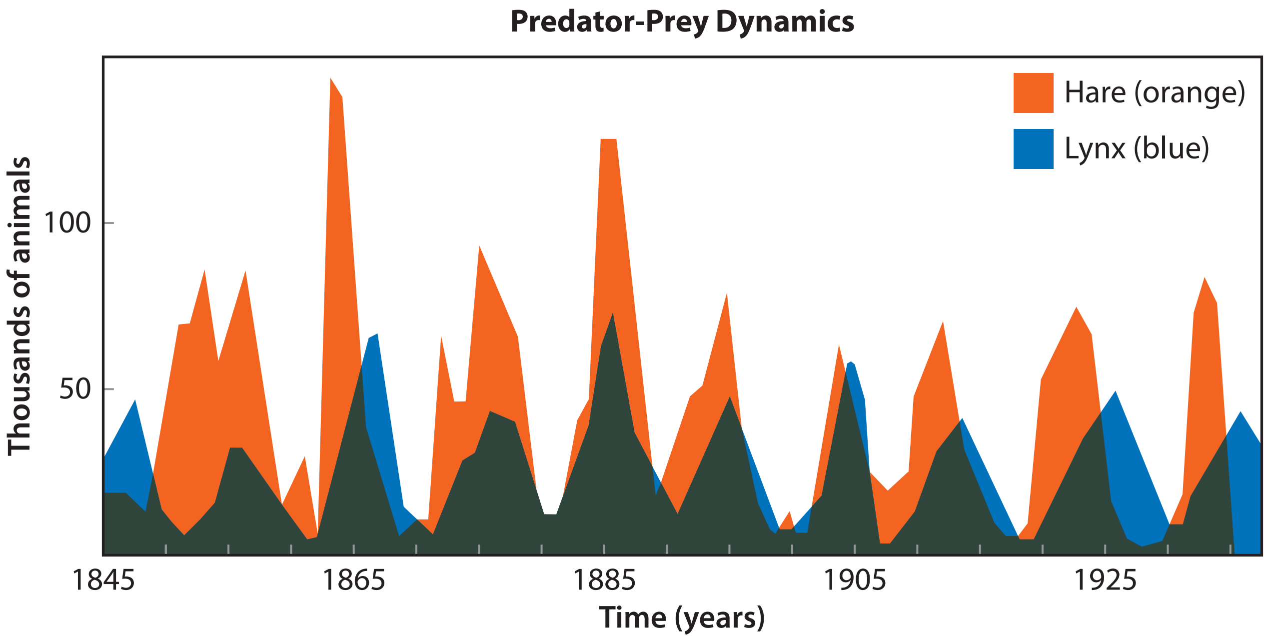
Harmony in Nature

Dynamic Equilibria

In the boreal forests of Canada, the lynx and the snowshoe hare exhibit a classic predator-prey population cycle. The lynx is dependent on the hare for food. The hare eats a variety of plants but is vulnerable to predation, and it can have trouble finding enough food, too. When hare numbers decline, the lynx population takes a few years to start declining. During periods of hare scarcity, female lynx have more trouble reproducing, and many lynx kittens die soon after birth. However, the decline in the lynx population allows the hare population to rebound. This occurs quickly because hares mature at a young age and breed well. The lynx population takes longer to rebound because the lynx does not mature quite as quickly and they do not produce as many young. Instead of having populations that remain balanced, the lynx and hare show what ecologists call dynamic equilibria—populations that fluctuate up and down as they affect each other.

Dig into Data

What do you notice in the graph about the numbers of hares and lynx in relation to each other?

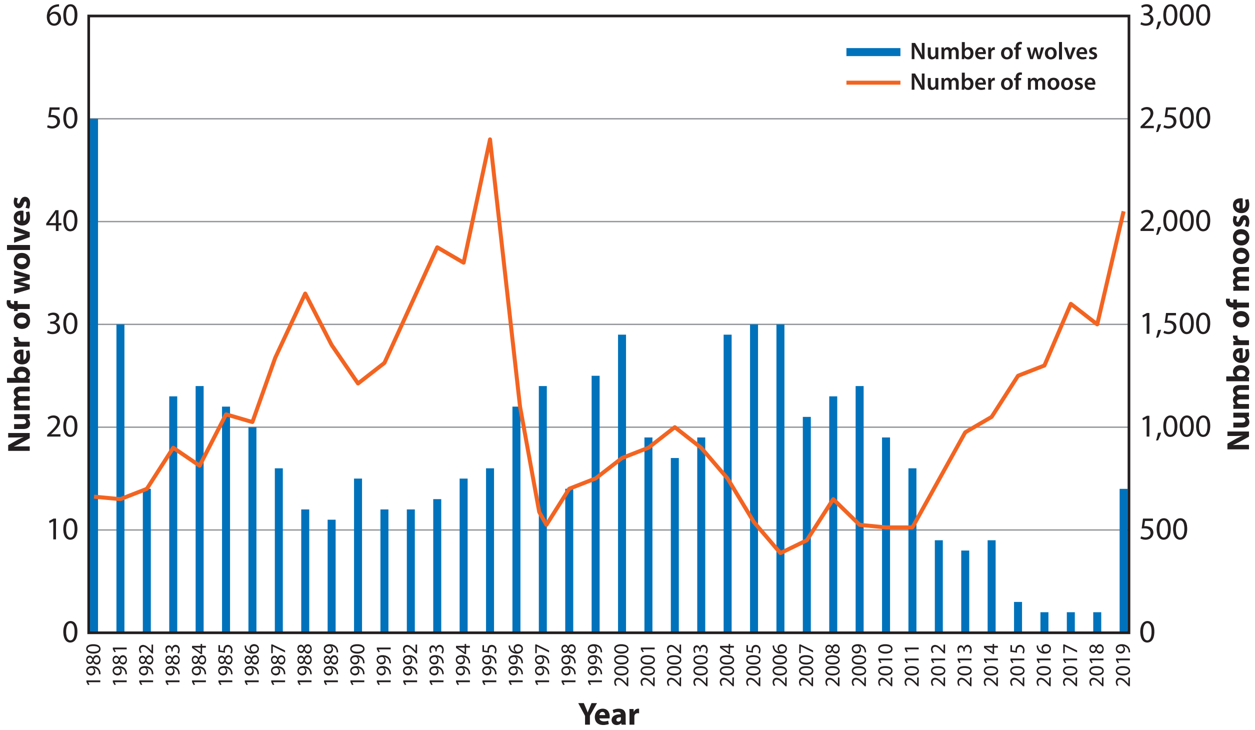


Isle Royale Wolves and Moose

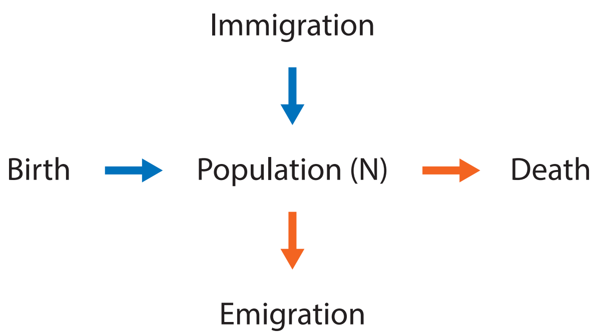
Isle Royale is a 207-square-mile island in northern Michigan. Wolves and moose migrated to the island long ago. The wolves probably got there by walking over the frozen lake in winter, while the moose are thought to have arrived on the island by swimming. Resident populations have lived there for over a century, engaging in predator-prey population cycles.

The moose population can be replenished by moose swimming to the island, but ice bridges and human intervention are the only ways to bring more wolves to Isle Royale. Recently, the wolf population got so low that scientists began the process of applying for permission to bring in several dozen wolves from elsewhere. Without a healthy population of wolves, the moose population could soar to the point that they could overgraze on plants of the island's forests.

Wolf and Moose Populations on Isle Royale (National Park Service data)



Animal populations rise and fall due to four factors. If the sum of the death and emigration rates is higher than the sum of the immigration and birth rates, the population is probably in decline. In some cases, such as islands that become cut off from sources of immigration, population change is entirely about the birth and death rates.



The Bottleneck Effect

October 12, 2020

It's close to dusk on Southeast Farallon Island near San Francisco, California. We're wrapping up another day watching for white shark predation on northern elephant seals. The seals are mainly juveniles that spend much of the year in other colonies of the California coast. The Farallon Islands offer food in the water as well as haul-out spots tucked into their rocky shorelines. The downside is, obviously, the presence of great white sharks, which also spend much of the year elsewhere but come here to feast on seals. A century ago, this predator-prey dynamic was probably absent from these islands, at least for this species of seal. In the 18th century, northern elephant seals and northern fur seals were all but wiped out by humans. There was a big trade in seal furs at the time. The Marine Mammal Protection Act has protected seals and sea lions since 1972.

The large-scale hunting of elephant seals served as a bottleneck. The population was greatly reduced in a short span of time, leaving a very small population that had less genetic diversity than the original population. This is known as the bottleneck effect. Picture a bottle full of 100 marbles, with lots of different genes. Now imagine that 98 of the marbles vanish and only two remain. Those two marbles might be able to be the founders of a new colony of marbles, but the genetic diversity of the population is much lower.

In some small founding populations of other species, bottleneck effects have let certain genetic disorders become more common in the new population. To use the marbles analogy, if the two marbles that survive and keep the population going happen to have genes that are associated with some type of cancer, those genes are going to be more likely in the new population as it grows. Even if the population rebounds, many individuals within the population might suffer from cancer and die at younger ages than did their ancestors.

At one point, the entire northern elephant seal population was down to just 10 to 20 individuals. From that founding population more than a century ago, the population soared to about 150,000, most of which live in California's waters. It's unclear if the seals suffered from the bottleneck effect. That's something we're trying to figure out and part of why I'm out here watching for shark-seal interactions. When sharks prey upon seals, we race out by boat to collect seal tissue samples that might be floating in the water. This lets us run genetic tests on today's elephant seal population to determine how that bottleneck that a small number of seals passed through in the 18th century affects the gene pool of today's population.

Strategies for Survival and Reproduction

r-Selection

Some organisms live in environments that are unstable, or experience a lot of change. In an unstable environment, it can make more sense for a species to mature early and produce lots of small offspring that require little care. By producing lots of offspring, the odds are pretty good that at least some of those offspring will have characteristics—or just good luck—that allows them to survive in the environment. This means the parents' genes will be passed on to a new generation. By not spending a lot of energy and time caring for the offspring, the parents do not have to invest as much in the act of reproducing. This often allows them to reproduce earlier or more often. In general, this is a "quantity over quality" approach. Evolution has moved many species toward this reproductive **strategy**, which is known as *r*-selection.

The chum salmon, *Oncorhynchus keta*, is an example of an *r*-selected species.

Number of eggs laid: 900–8,000

Time from egg fertilization to hatching: 3–4 months

Length at hatching: 30 mm

Time spent with mother: none

Maturity age: 3–5 years

Lifespan: 5 years

Adult mass: 5 kilograms

Spawning chum salmon spend time building and guarding a nest in a stream bed, but for the most part the offspring are entirely on their own after birth. Many of the offspring will not survive their first weeks.

Vocabulary

strategy, n. in biology, a behavior that occurs naturally in a population through evolutionary processes and reproduction (It does not require thought or deliberate actions of the species in the way that a strategy used by humans might. It is more like a pattern in how organisms exist over time.)

K-Selection

If organisms live in stable environments, a different reproductive strategy might make more sense. *K*-selected species tend to have long lives, mature late, and produce relatively few offspring that need more care. The offspring tend to be larger when they are born, and in some cases they receive a great deal of care from their parents for weeks or years after birth. This is a "quality over quantity" approach.

The African elephant, *Loxodonta africana*, is a *K*-selected species.

Time from egg fertilization to birth: 22 months

Number of offspring at one time: 1

Mass at birth: 110 kilograms

Time spent with mother: 4–6 years

Maturity age: 10–12 years

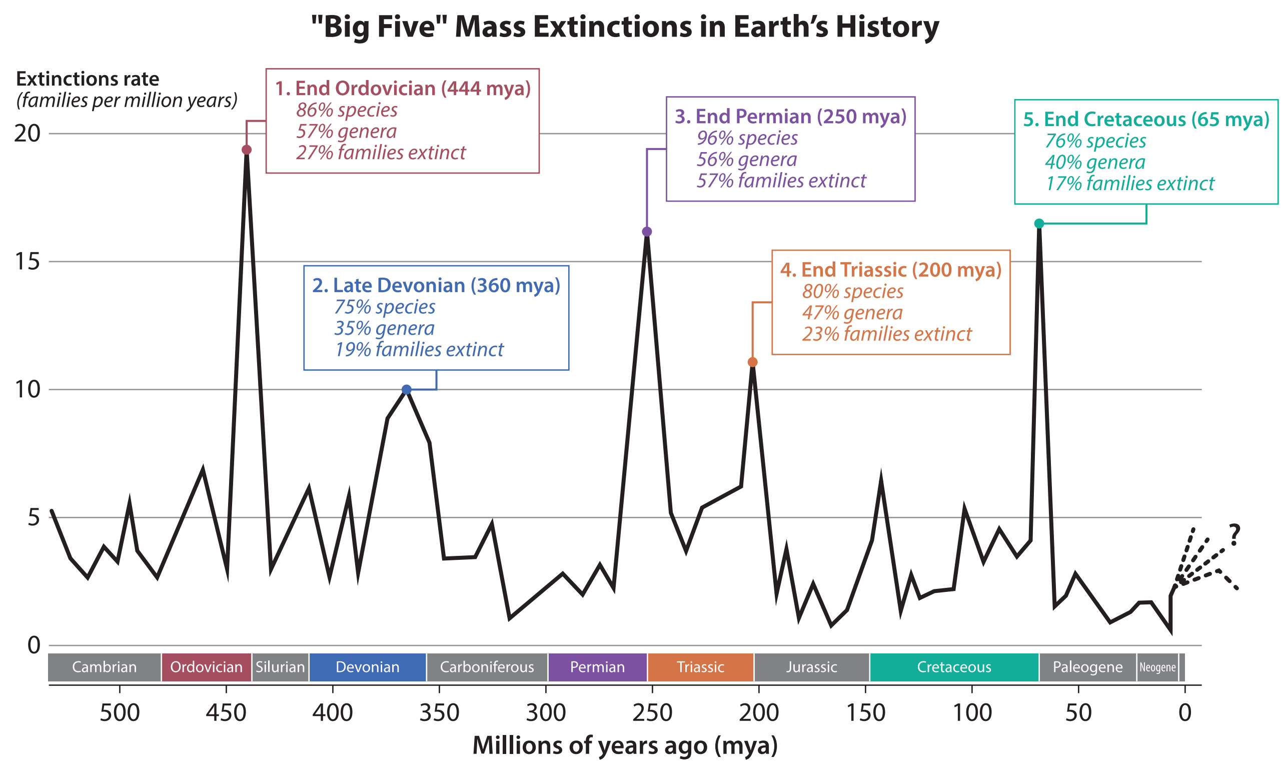
Lifespan: 60–70 years

Adult mass: 2,700 kilograms

A mature female African elephant gives birth to one calf at a time and will need to nurse that calf for four to six years. This is a tremendous investment of time and energy, but the payoff is a higher chance of survival for the offspring. Humans are another *K*-selected species.

Extinction Events

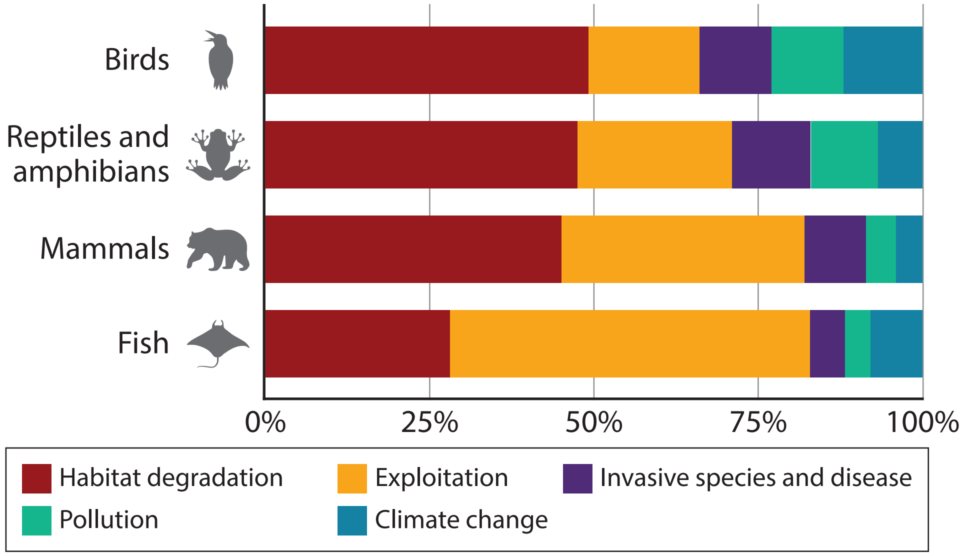
Every million years or so, about five families—groups of related species—have gone extinct. This is called background extinction. It occurs without a large-scale natural disaster or major event serving as a cause. However, some major extinction events have wiped out half of all families and over 90% of all species within relatively short periods of time.



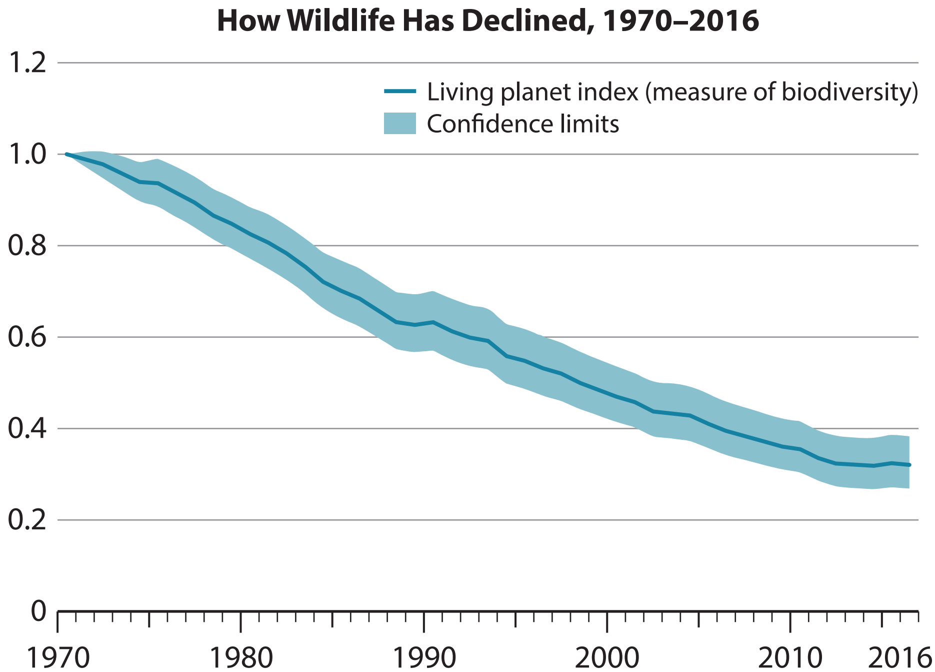
Dig into Data

Which of the five mass extinctions in history caused the highest extinction rate?

Analysis of some trends in biodiversity loss today suggests that humans are setting up Earth's biosphere for a sixth mass extinction event. There are five major causes of species loss, as shown in the figure below.



Scientists with the Zoological Society of London established a living planet index based on wildlife numbers in 1970 and declines in populations since then. That index has dropped by 70%.



Connection

What could a 70% drop in the living planet index indicate, and how would this affect Earth as a whole?

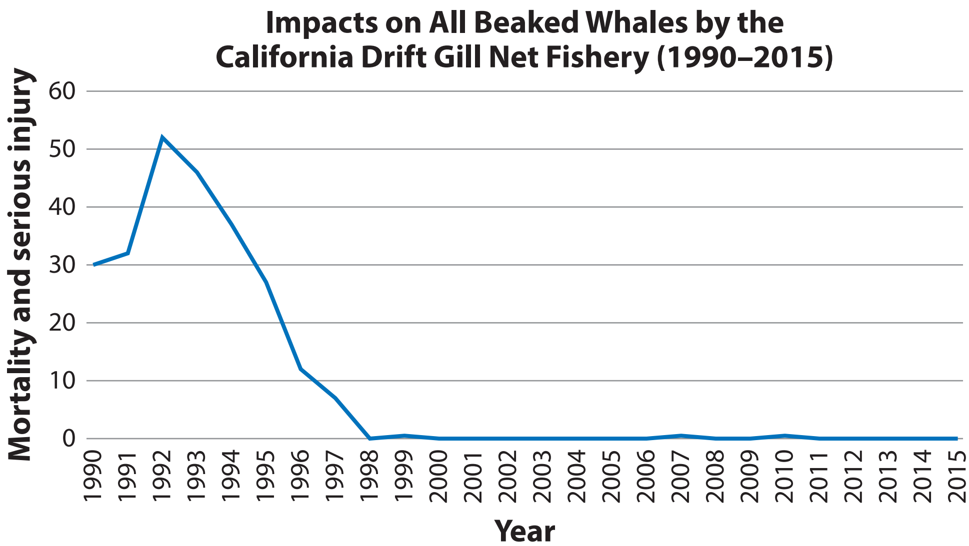
Bans, Boycotts, and Bargains

People's environmental concerns can lead to change. For example, when the United States passed the Marine Mammal Protection Act in 1972, it meant immediate protections for marine mammals from practices that harmed those animals in U.S. waters, including the trade of products made from marine mammals. However, that act, which was a federal law, did not protect marine mammals that were being harmed in international waters or in the waters controlled by other countries.

People who wanted to stop whaling in non-U.S. waters launched the "Save the Whales" campaign in 1977. This was aimed at compelling other countries to stop hunting whales by boycotting goods made in those countries. For example, the campaign called for broad boycotts of goods made in Japan and Russia. The goal was to exert market pressure on the nations that were whaling. If, for example, a Japanese television manufacturer saw its sales to the United States decline due to the boycott, it might exert its own pressure on the Japanese government to ban whaling. In fact, Japan did ban commercial whaling by 1986. However, it allowed "scientific" whale harvests to continue, and the meat from those "sampled" whales ended up in food markets.

This popular T-shirt in the 1970s called for people to boycott products made in Japan and Russia, two nations that were still hunting whales for commercial purposes.

In California, a relatively small fleet of boats that uses drift gill nets to catch swordfish has been under fire for decades because the gill nets also tend to snag dolphins, sea lions, and other marine mammals that are supposed to be protected. This kind of "incidental take" of marine mammals in fisheries was not banned by the Marine Mammal Protection Act. So as long as the catch of these mammals in the gill nets is not deliberate, it is not illegal. Pressure from people who felt the fishery was getting away with killing or injuring innocent marine mammals led to the National Marine Fisheries Service's new requirement that gill net vessels carry observers on board to monitor the catch and record incidents of marine mammal interactions with the fishing gear. The nets also needed to have pingers attached to them. The pingers emit a sound that warns some marine mammals away from the nets. Pingers and other rules have reduced the incidental take of marine mammals in the drift gill net fishery. The rules worked to protect the mammals, while the fishers were allowed to keep fishing.



Word to Know

A *boycott* is a deliberate, organized refusal to purchase certain goods or services.

Dig into Data

How do you think the graph of the incidental take of beaked whales would look if the National Marine Fisheries Service did not have rules that protected marine mammals?

Stability through Diversity

A Lesson from the Irish Potato Famine and the U.S. Rust Belt

When an ecosystem relies a lot on just one thing—one type of tree or one crop—it's vulnerable to catastrophe. Diversity is a source of stability in ecosystems, economies, and agriculture.

In the early 1800s, the human population in Ireland was growing quickly, but there wasn't enough food. To solve this problem, potatoes were planted, and the potato became the staple of the Irish diet. This worked out well for a while, because potatoes can be planted by cutting them into pieces instead of waiting for seeds. Virtually all of the potatoes growing in Ireland by the 1840s were clones of the original type of potato that was planted decades before. This monoculture of potatoes was not genetically diverse, and it made the potatoes especially vulnerable when a fungus, called the potato blight fungus, came along and infected the plants. Potato blight destroyed the primary source of food for Ireland for many years, leading to the starvation and death of a million people and mass emigration of Irish people to other nations. If a greater variety of potatoes had been planted, some of them would have been resistant to the blight, and those varieties could have been planted in greater numbers in the following seasons.

The lack of genetic diversity in the potatoes growing in 1800s Ireland made the crop more vulnerable to blight and led to famine and starvation after the potatoes were infected.

We see a similar vulnerability in economies, especially those of small towns. If a small town has more than half of its workers employed by a factory or employed by businesses that depend on the factory, the closing of the factory can leave thousands without work. The person who installed car seats for 20 years may not have another good job to turn to, and the people who cut that person's hair, sold them gasoline, bagged their groceries, taught their children at school, and provided other services could also be out of work. An economy that has more going on is less likely to be devastated.

Why I Plant Monocrops

I'm a farmer in southern Illinois. I have 800 acres that are not irrigated. That means my crops need rain and weather that isn't too extreme. While I would love to grow a variety of vegetables such as tomatoes, eggplant, and lettuce greens, it simply isn't an option for me. What can I grow and make a living on? Corn and soybean. The rainfall we get here is adequate for either, and by planting one crop for two years and then switching to the other for one year, the soil doesn't get too sapped of its nutrients. Sometimes I have a mix of soy and corn, but a rotation usually makes more economic sense for my farm. In the winter, I plant clover so the soil doesn't erode too much, and some nitrogen gets back into the soil before I plant the next season's corn or soy. But that's about all I can do, despite the call for diversifying America's farms and moving away from monocropping. If I were to switch to the kind of diverse farming that the average American might hold in their imagination as a picturesque, harmonious ideal, I would need a major influx of money (lottery?), or my industry would need to stop getting subsidies from the government for soy and corn. For example, a few years ago, corn farmers received $2 billion in subsidies from Uncle Sam, which meant it was better for me to plant corn than anything else. The economics of this business and the physical realities of the climate in this area do not give me many options. Until things change, I am basically stuck planting soybean or corn on all 800 acres.

Word to Know

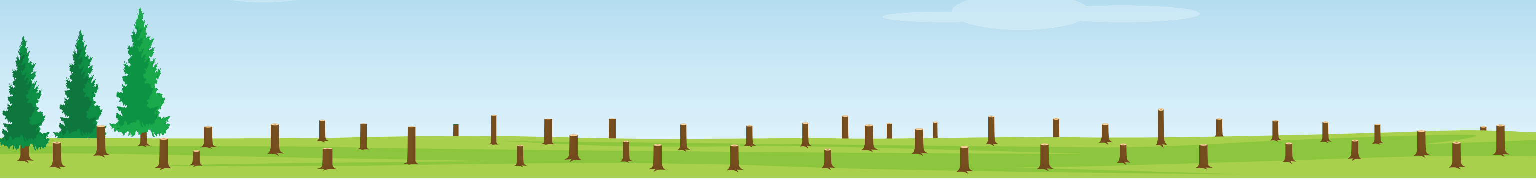
A *subsidy* is a payment from the government to an industry so the product of the industry has a relatively low price and remains abundant and the industry stays in business.

Selectivity in Logging and Fishing

Forest ecosystems are often affected by the extraction of timber, which is a term for the tree trunks that are cut down and then cut into lumber. There are several ways to harvest timber.

Clear-cutting

Pros of clear-cutting:
- easy
- inexpensive
- Trees can be replanted to produce a new forest of uniform size and composition.



Shelterwood logging

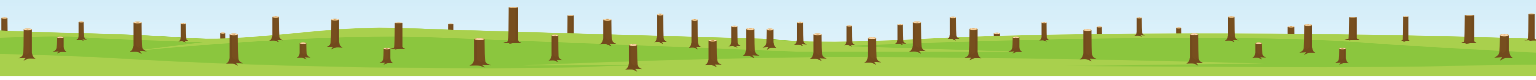
Pros of shelterwood logging:
- Some habitat is preserved.
- The forest can regenerate itself.

Selective cutting

Pros of selective cutting:
- Only selected trees are removed.
- the least disruptive logging to the ecosystem.

Cons of clear-cutting:

- Habitat is destroyed.
- Soil could degrade and erode if forest is not replanted.



Cons of shelterwood logging:

- more expensive than clear-cutting
- Mature stands of trees must be selected and protected.

Cons of selective cutting:

- most expensive logging method
- Removing selected trees can result in damage to the ecosystem.

Selectivity in Fishing

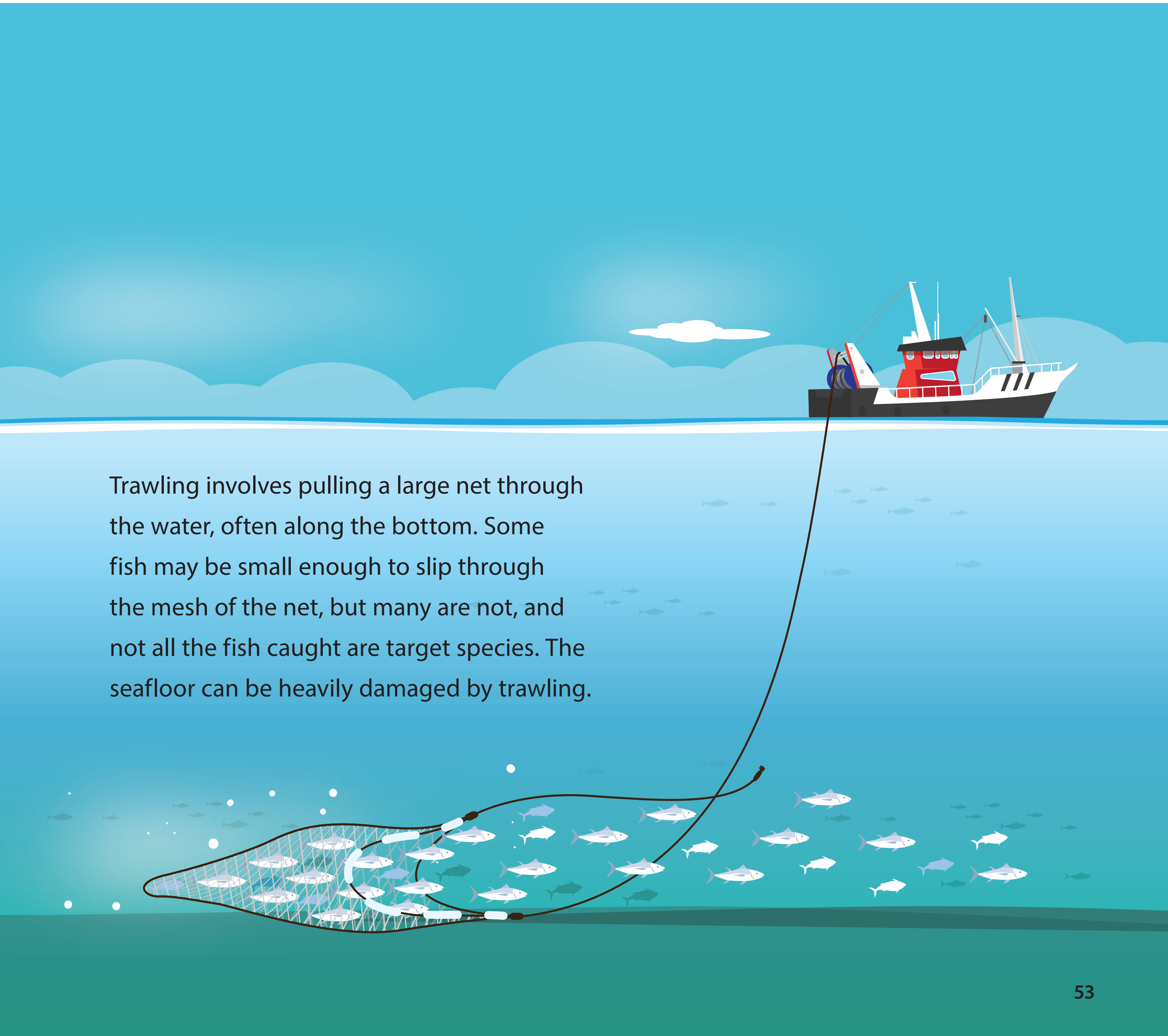
Fishing is different from logging because in most cases the target species in a fishery are moving around, sometimes several thousand miles each year. Marine organisms are also harder to see than trees. But there are some similarities to the approaches that fishers and loggers take to resource extraction. Some fishing gear is not very selective. Other gear types are very selective and result in less **bycatch** and less degradation of marine habitats.

Hook-and-line fishing is more selective than trawling, but depending on the gear used, it can also catch nontarget species.

Spearfishing is not very efficient, but it avoids harm to nontarget species.

Vocabulary

bycatch, n. the incidental capture of organisms that are not targeted by a fishery or fishing gear



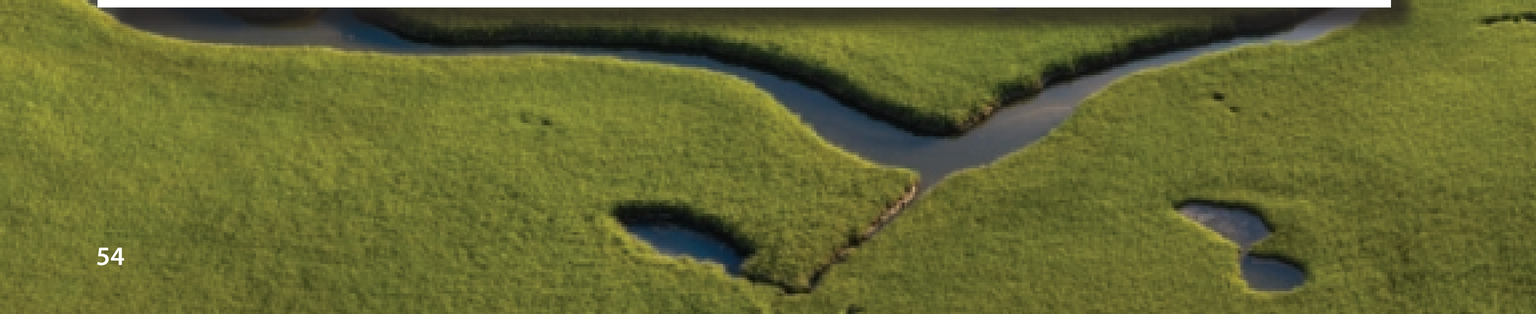
Trawling involves pulling a large net through the water, often along the bottom. Some fish may be small enough to slip through the mesh of the net, but many are not, and not all the fish caught are target species. The seafloor can be heavily damaged by trawling.

Tillman Marsh Town Hall

Mayor: Fellow citizens, thank you for attending our town hall, where the topic of discussion tonight is Tillman Marsh. You may have read the letters that our own neighbors Dorothy Tillman and Stu Moore wrote in *The Stillwater Tribune* regarding their positions on what to do about Tillman Marsh. Tonight they are here to speak more directly on the various issues and seek your understanding and support so that we, as a community, can make an informed decision. Welcome Ms. Tillman and Mr. Moore.

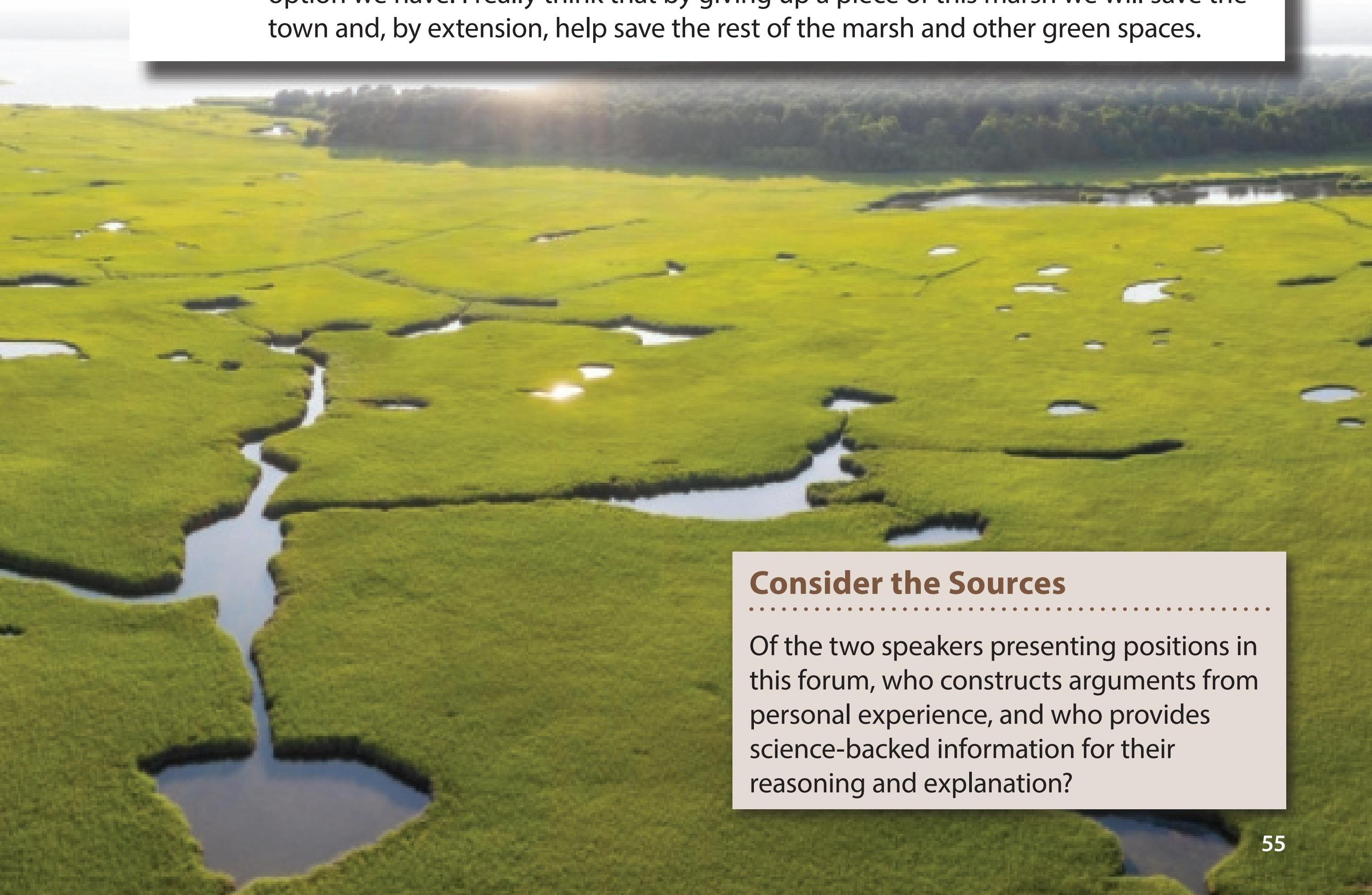
Dorothy: I'm Dorothy Tillman, and I'm here to speak on behalf of a group I'm proud to have founded, Friends of Tillman Marsh. I'm biased in favor of preserving this marsh because I'm a Tillman, but first and foremost I'm a human being who understands that I'm just one tiny piece of this town and the ecosystems that compose it. It's easy for us to overlook each other and the contributions we make to our town, just as it's easy to overlook what the fish, birds, crabs, clams, marsh grasses, algae, and even the mud and peat do where the land meets the sea, in Tillman Marsh. Those ecosystem services are so valuable, both to our town and to the larger system—Earth—that we all rely on. We should not sell out our town, our ecosystems, our fellow organisms, and the planet for a short-term influx of money in the form of shops, restaurants, and condos. Thank you.

Stuart: Good evening, everyone. I'm Stuart Moore, but you know me as Stu. I appreciate the select board hosting this debate. I'd like to thank Ms. Tillman for her advocacy on behalf of the Friends of Tillman Marsh. I consider myself a friend of the marsh, too, but as a man whose made his living off the sea for a long time, I'm here to bring some reality to this discussion. Our town needs some diversity of economic activity to complement the biodiversity of Tillman Marsh. We need to find a balance between conserving and valuing that special habitat and conserving and valuing the people and economy of this town, which has fallen on hard times. We should not assume that developing a piece of the marsh into an engine of economic growth is an all-or-nothing, black-and-white thing. Much of the marsh will remain intact, including the creek and just about every inch of the marsh that is in direct contact with the sea. Fish will continue to come and go, and I'll continue to clam. The shops and restaurants and condos will bring much-needed income and tax revenue to the town. Thanks.



Dorothy: Stu, I admit that you are correct that habitats and ecosystems can be reduced in size without necessarily destroying them. You're right about that. But what concerns me is not just the footprint of the development that's proposed, but the amount of damage that could be done during construction and how the development will affect everything around it once it's done. The proposal caps the affected area at 50% of the marsh's current area, but there's no telling what percentage will be receiving sand, mud, concrete dust, and other stuff that could spill out from the construction site. Marshes are sensitive. You can't just put up an orange plastic fence and some hay and assume everything's fine. The same is true when this thing is done. Where will rainwater go? Does it all get diverted into the marsh or the creek? Does it become a heat island that heats the air above the marsh? Too many questions and unknowns. We know what the marsh does, and it's taken hundreds or maybe thousands of years to reach its current state. Let's respect that by leaving it be!

Stuart: Dorothy, nothing is permanent. Some of the marsh is probably going to erode into the sea as climate change raises the sea level in the coming decades. If the marsh is strong enough to withstand hurricanes and other periodic threats, I think it'll be okay with some construction dust and storm runoff. State regulations on coastal development will keep a tight leash on the construction company so pollution is controlled. I don't like the idea of losing any of the marsh, but the fact of the matter is we really need more revenue in this town, and the proposed development is the best option we have. I really think that by giving up a piece of this marsh we will save the town and, by extension, help save the rest of the marsh and other green spaces.



Consider the Sources

Of the two speakers presenting positions in this forum, who constructs arguments from personal experience, and who provides science-backed information for their reasoning and explanation?

Glossary

bottleneck effect, n. an event in which a species undergoes a sudden reduction in population

boycott, n. an act of protest expressed by withdrawal of interaction with a party or use of a product

bycatch, n. the incidental capture of organisms that are not targeted by a fishery or fishing gear

dynamic equilibrium, n. a state of balance among continuous processes in a system

ecology, n. the study of the relationship between living organisms and their environment

economics, n. the social science concerned with the production, consumption, and distribution of resources and wealth

ecosystem dynamics, n. changes within the processes and system in a living environment

ecotourism, n. responsible travel to natural areas with the goal of conservation of the environment

endemic species, n. a type of organism found only in one place

extinction, n. the termination of a species

extraction, n. removal of a resource from the place of its natural occurrence

habitat fragmentation, n. the breakup of a natural habitat into smaller pieces

invasive species, n. a type of organism that is not native to an area and does harm to an ecosystem, often by outcompeting other species for resources or preying on native species

***K*-selection species, n**. species whose populations are maintained by lengthy parental care of few offspring

land cover, n. the physical material covering an area of Earth's surface, such as vegetation, water, asphalt, bare soil, sand, etc.

non-native species, n. a type of organism living in an area as a result of having been transported there unnaturally

population sampling, n. counting organisms within a small subset of an area in order to mathematically estimate the probable size of the whole population

quadrat, n. a designated space within an ecosystem marked for counting a population sample

reproduction, n. the creation of offspring by organisms

resource, n. a substance taken from the natural environment to support or enhance human life

***r*-selection species, n**. species whose populations are maintained by high reproductive capacity

science literacy, n. the ability to read, hear, and comprehend information about scientific topics and demonstrate understanding in discussion and through writing population

social media, n. websites and applications that allow users to participate in sharing content on the internet

strategy, n. in biology, a behavior that occurs naturally in a population through evolutionary processes and reproduction

subsidy, n. a payment from the government to an industry so the product of the industry has a relatively low price and remains abundant and the industry stays in business

transect, n. a straight line through a natural area guiding where observations or measurements are taken

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