

A lynx is walking through a snowy forest at night. The lynx is in the center-right of the frame, looking towards the camera. The background is filled with snow-covered evergreen trees, and the ground is covered in a thick layer of snow. The lighting is dim, creating a dark and moody atmosphere.

Engineering Solutions for Protecting Ecosystems

Chapter 29 of 29 • Humans and Changing Ecosystems

Lesson 29: More people, more use per person. How do we choose fixes that protect ecosystems?

PHENOMENON

Ten-year waves and one rising line

For about a century, Hudson's Bay Company traders recorded how many lynx pelts trappers sold each year in northern Canada. The counts rose and fell in waves about ten years apart, just after waves in snowshoe hares, the lynx's main food. Over the same years the human population only climbed, from about 1 billion around 1800 to about 8.2 billion in 2025 (UN estimate).

- Notice: what repeats in the lynx record? What never repeats in the human record?
- Wonder: what stops a lynx population from climbing forever?
- Predict: where does the food for 8.2 billion people come from, and what happens there?





LEARNING TARGETS

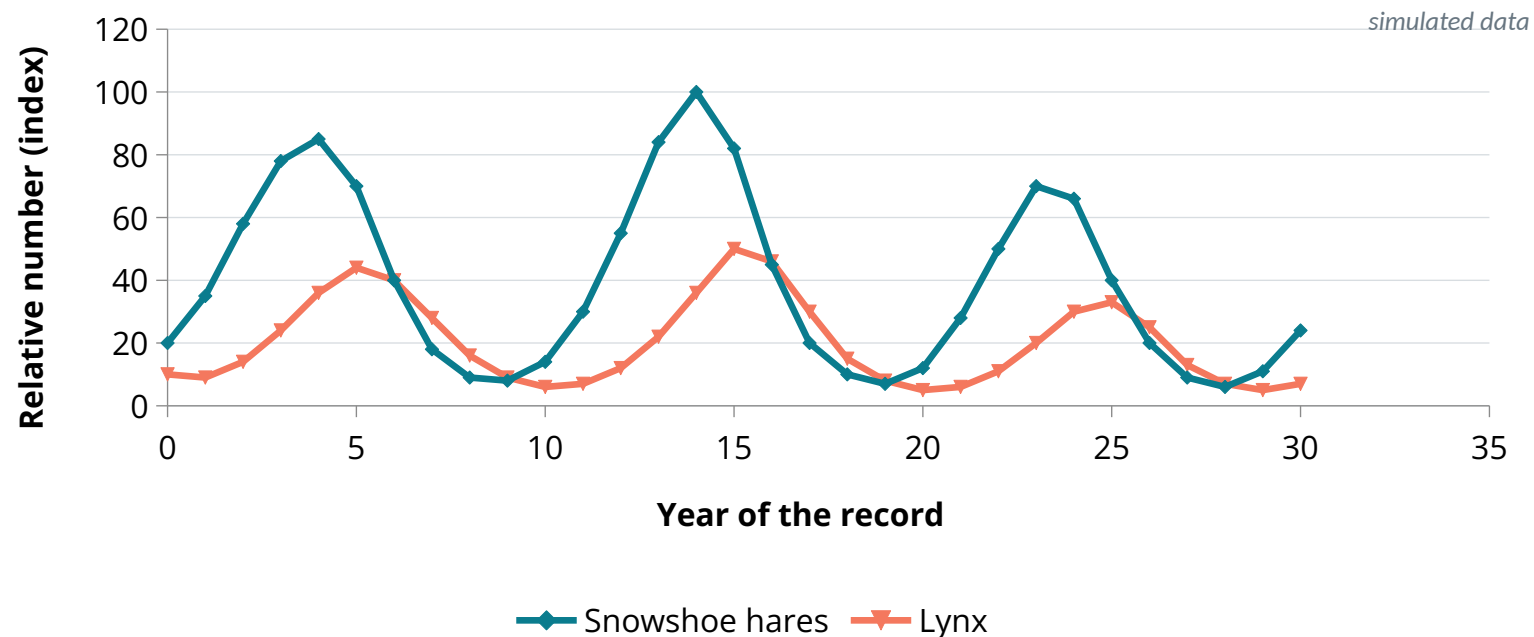
What you will be able to do

- 1 Explain how the number of people and the use per person together set the demand on ecosystems.
- 2 Explain why lynx and hares rise and fall while the human population keeps rising.
- 3 Trace a human disruption through an ecosystem and back to people.
- 4 Write precise criteria and constraints, then test a net design against them.
- 5 Weigh competing solutions with a criteria matrix and say what science can and cannot decide.
- 6 Compare monitoring data with a healthy-ecosystem model to judge whether a fix is working.

MODEL

Snowshoe hares and lynx: waves that repeat

Model: Hare and lynx records (teaching dataset)



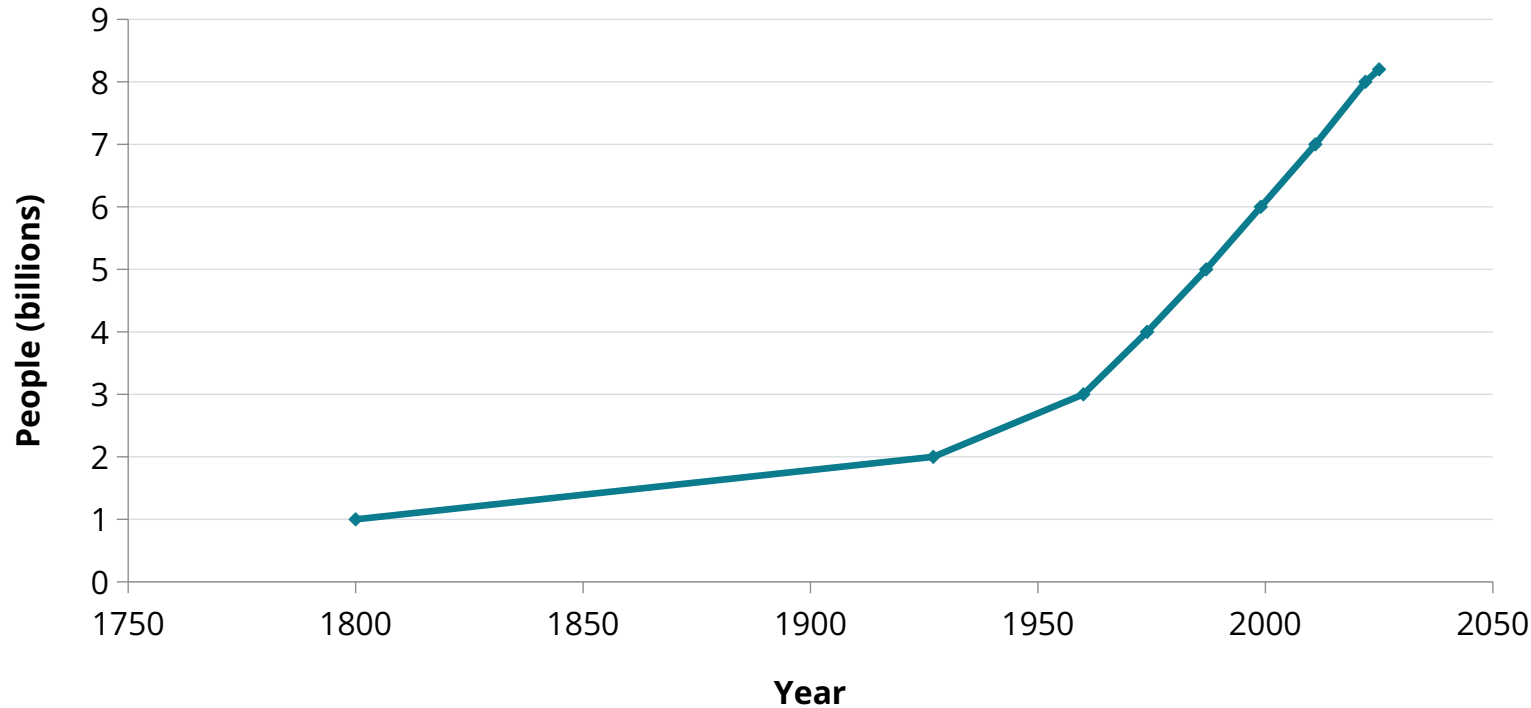
Simulated teaching data shaped like the fur-trade records: peaks about 9 to 10 years apart, lynx peaks a year or so after hare peaks. These are not the actual counts.



MODEL

People on Earth, 1800 to 2025

Model: World population milestones



United Nations estimates: about 1 billion around 1800 (the UN dates it to 1804); 8 billion on 15 November 2022; about 8.2 billion in 2025 (World Population Prospects 2024).



Why the wild waves fall, and why scientists still argue

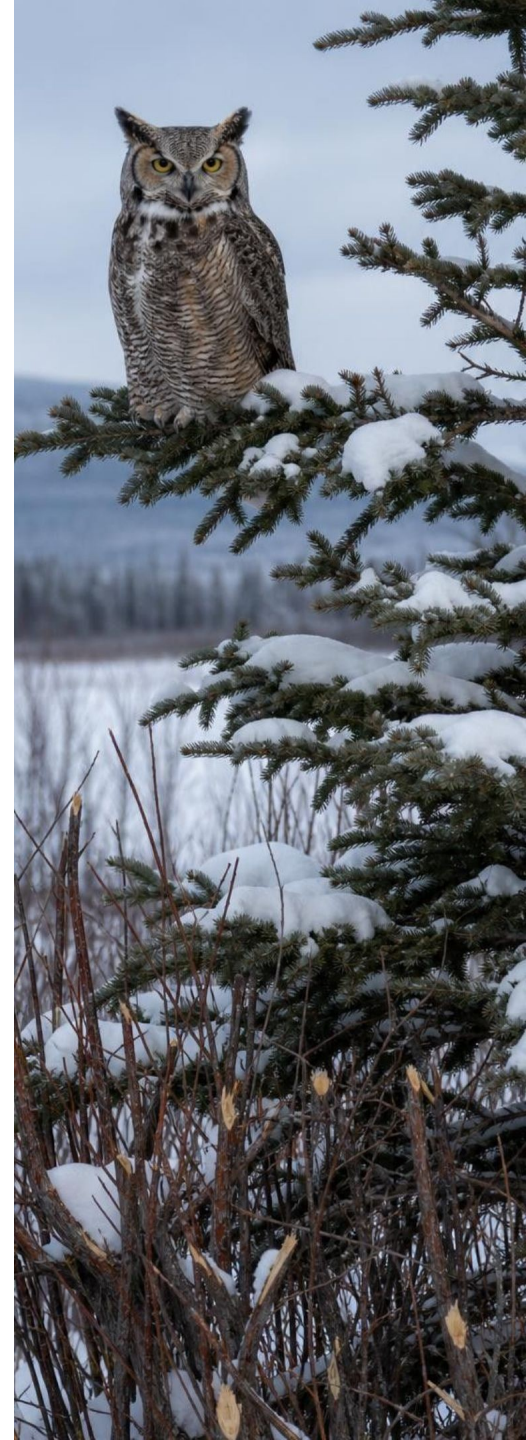
Plenty of hares: lynx raise many kittens. After hares crash, most kittens die and adults starve or leave.

Hares are eaten by lynx, coyotes, owls and hawks, and a crowded forest runs short of good winter twigs.

Yukon experiments that added food and fenced out predators suggest food and predators act together.

The old records count pelts sold, which also rose and fell with trapping effort and fur prices.

The big idea: a wild population lives on the food its own ecosystem makes this year.





Why the human line has not turned down

- People do not rely on one food or one place: trade moves food, fuel and wood around the world.
- Farm machinery, fertilizer, irrigation and new crop varieties made far more food per hectare.
- Clean water, vaccines and medicine lowered death rates, especially for young children.
- Growth is slowing: under 1 percent a year now, about 2 percent a year in the 1960s (UN).
- UN projection (2024): a peak of about 10.3 billion people in the mid-2080s.
- Every person still draws food, water, wood and energy from ecosystems somewhere.

CHECK FOR UNDERSTANDING

Quick check: one forest, two populations

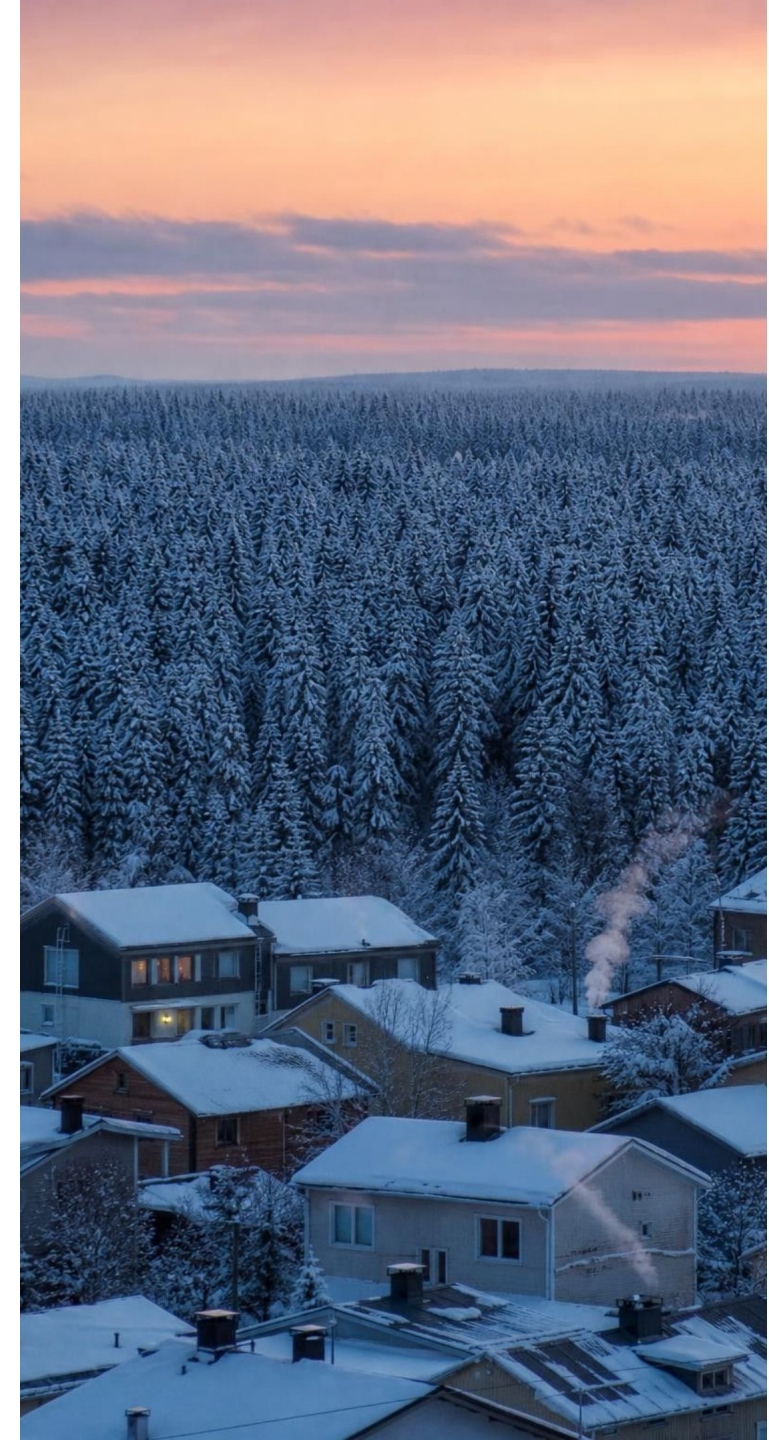
A lynx population and a town of people both get food from the same forest. A bad year cuts the forest's food in half. Which population is more likely to shrink within a year or two, and why?

A. The lynx: they can only eat what this forest makes this year.

B. The town: each person needs more food than a lynx does.

C. Neither: populations do not respond to their food supply.

D. Both equally: every population follows the same rules.



Total use = number of people × use per person

Per capita means per person: divide a group's total by its number of people.

Total use = population × per capita use.

Double the people, same use each: total doubles. Double both: the total is four times as big.

The lesson's graph shows world energy use per person more than doubling since 1900.

If total use is faster than an ecosystem replaces a resource, the stock shrinks.





Vocabulary in context

Words for counting demand

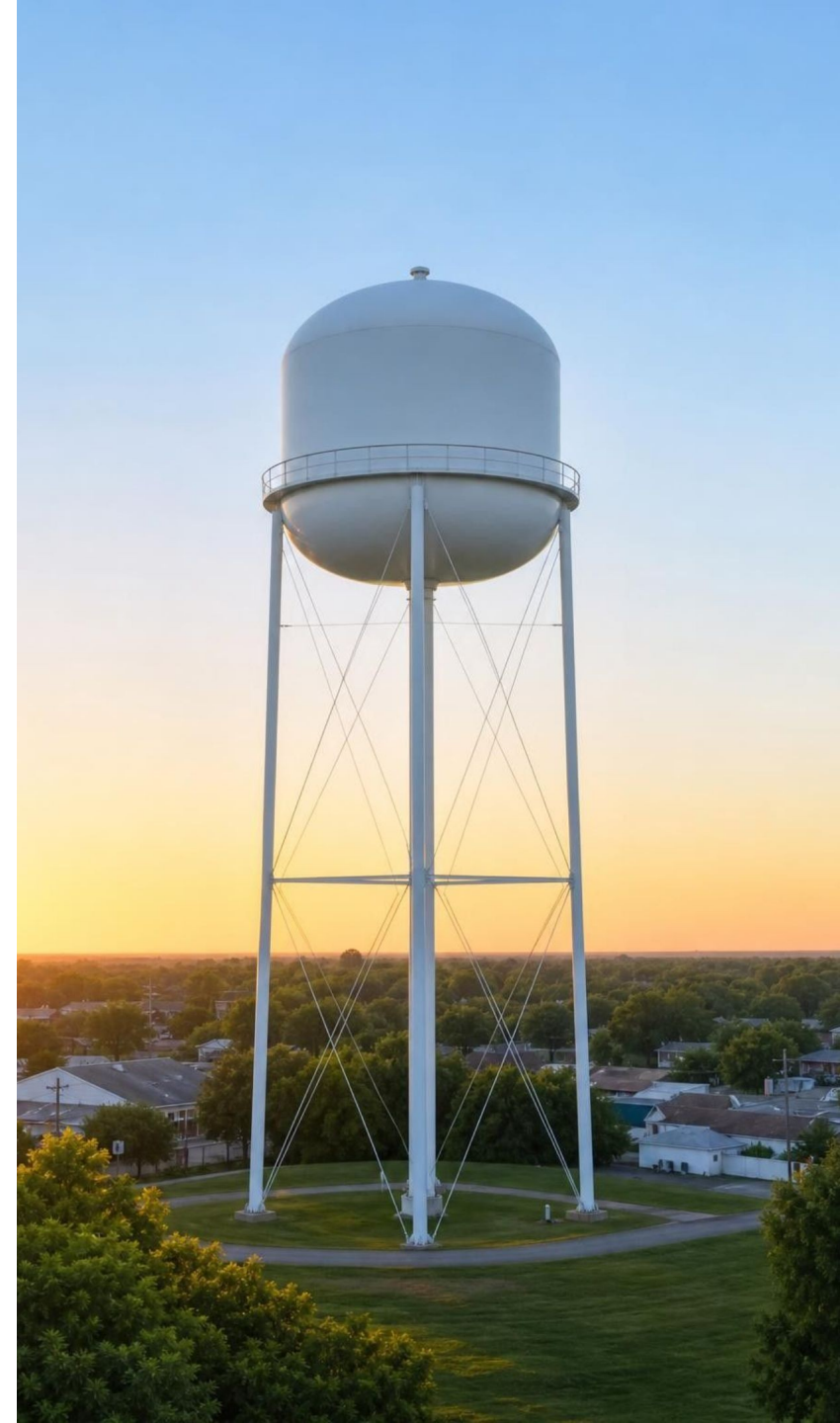
- **per capita:** Per person: a group's total divided by its number of people. *A town of 20,000 using 3 million liters a day uses 150 liters per capita.*
- **ecosystem services:** Benefits people get from working ecosystems. *A marsh filters nitrogen out of water and soaks up storm surge.*
- **biodiversity:** The variety of species, their numbers and their habitats in a place. *A shaded coffee farm holds many more bird species than a full-sun farm.*

CHECK FOR UNDERSTANDING

Quick check: per capita math

- Bonus: what if the town stayed at 20,000 but each person used 20 percent more?
- Which change raised total use more, and why?

A town of 20,000 people uses 3,000,000 liters of water a day. What is the per capita use? How much would it use in total if it grew to 30,000 people and each used the same?

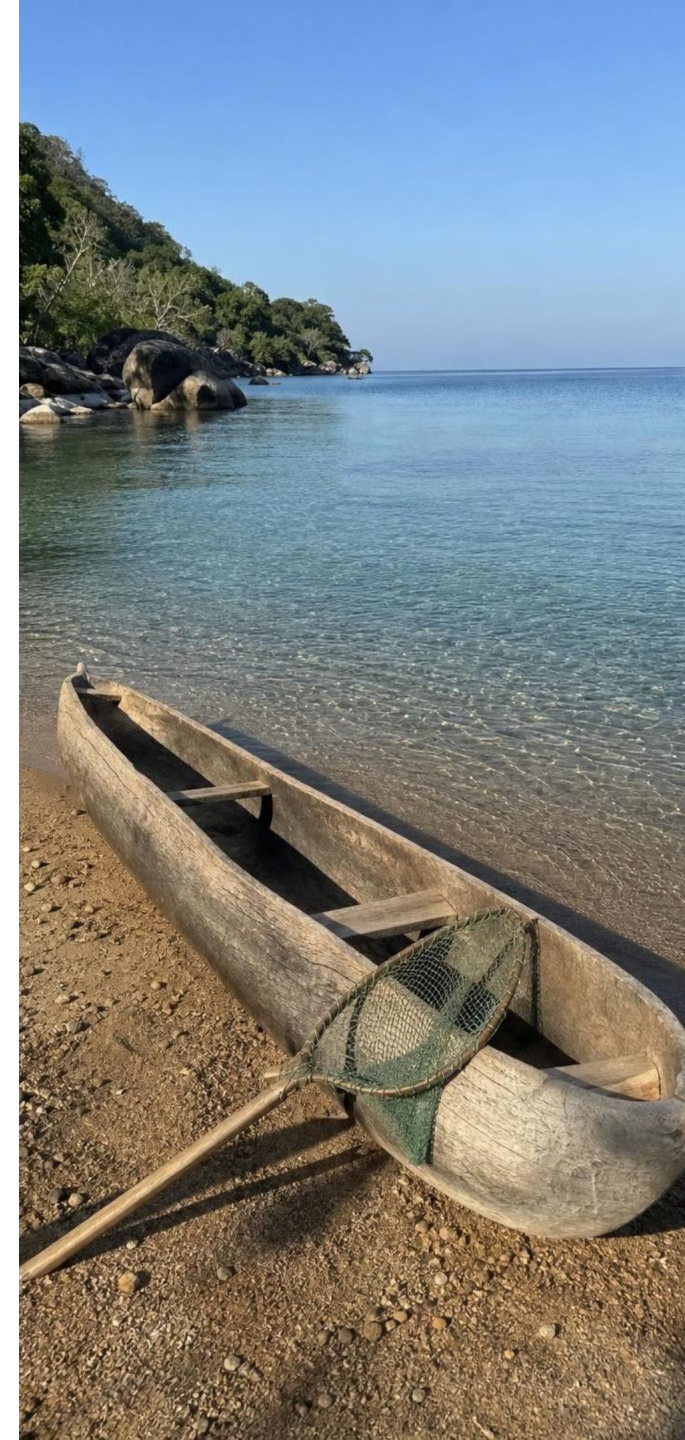


Lake Malawi: a chain that loops back to people

Model: Overfishing and bilharzia

- 1 More people fishing with fine-mesh nets →
(small fish are caught too)
- 2 Fewer small snail-eating fish →
(snails lose a predator)
- 3 More freshwater snails →
(snails host the parasite)
- 4 More parasite larvae in shallow water →
(larvae burrow into waders' skin)
- 5 More people infected with bilharzia

The chain as the lesson describes it. Field studies found less infection where snail-eating fish were more common, which supports the chain but does not prove every step.





VOCABULARY IN CONTEXT

Words for harm to living things

- **over-exploitation:** Harvesting a species faster than its population can replace what is taken. *Netting small fish along with big ones at Lake Malawi.*
- **by-catch:** Animals caught by fishing gear that the fishers were not trying to catch. *Sea turtles tangled in a net set for swordfish.*
- **habitat degradation:** Damaging a natural area so it can no longer support its living things. *Clearing tropical forest to plant full-sun coffee.*

Six ways people disrupt ecosystems

MODEL

Model: The lesson's six disruptions

Center: Human disruptions

Over-exploitation: Overfishing at Lake Malawi let disease-carrying snails multiply.

Emerging disease: Nipah virus passed from fruit bats to farm pigs to farmworkers.

Invasive species: Carp that escaped fish farms crowd out native fish.

Pollution: Plastics break into fragments that turtles and seabirds swallow.

Habitat degradation: Forest cleared for full-sun coffee removes winter habitat for warblers.

Climate change: Rising seas flood coastal cities and drown marshes.

The lesson's six categories, each with its example. Real problems often combine several.



VOCABULARY IN CONTEXT

Words for new arrivals and long-term change

- **invasive species:** A species moved by people to a new place, where it causes harm. *Quagga mussels, found in Lake Mead in 2007, now clog pipes in California reservoirs.*
- **emerging disease:** A disease newly appearing in people, often after new contact with wild animals. *Nipah virus in Malaysian pig farmers in 1998 and 1999.*
- **climate change:** A long-term shift in Earth's climate, now driven mainly by burning fossil fuels. *Higher seas make high-tide flooding more common on California's coast.*





THINK, PAIR, SHARE

Discuss: which disruption is hardest to undo?

- Think about time: how long would recovery take?
- Think about spread: can the harm move on its own?
- Think about extinction: can a lost species come back?

Of the six disruptions, which would be hardest to reverse once it has happened? Rank your top two and give a reason for each.

Engineers start by defining the problem

- Criteria: what a solution must do, stated so you can test it. 'Keep 8 of every 10 big fish.'
- Constraints: limits it must work within, such as cost, materials, time, laws and skills.
- Lake Malawi: the fix had to be cheap, easy to make and still feed families.
- Nipah: keep pigs away from trees where bats roost; wear gloves and protective gear.
- Tradeoff: shade coffee gives fewer beans per hectare but keeps forest birds and pollinators.





CHECK FOR UNDERSTANDING

Quick check: criterion, constraint or tradeoff?

- 1 The net must keep at least 8 of every 10 large fish it catches.
- 2 Each net can use no more than 20 strands of string.
- 3 Bigger holes spare small fish but let a few large fish escape too.
- 4 Fishers must be able to repair the net with tools they already own.
- 5 At least 8 of every 10 small fish must slip through.

Label each statement about a new fishing net C (criterion), K (constraint) or T (tradeoff).

MODEL

Test, compare, adjust: restoring Long Island Sound

Model: Monitoring against a model of a healthy sound

1

Measure nitrogen, oxygen and wildlife → (data)

2

Compare with the model of a healthy sound → (gap found)

3

Find the cause: too much nitrogen → (target chosen)

4

Act: limit nitrogen from sewage plants → (time passes)

5

Wait, then measure again → (repeat) (back to the start)

Scientists compare each round of measurements with a model that describes normal levels for a healthy sound.





What the Long Island Sound data showed

- 1987: high nitrogen and low oxygen across large areas of the sound's bottom water.
- Extra nitrogen feeds algae. Living algae add oxygen, but they soon die and sink.
- Bacteria breaking down the dead algae use up oxygen; fish and lobsters suffocate or leave.
- Low-oxygen area: about **208 sq mi** on average in 1987-1999,
about **83 sq mi** in 2021-2025.
- Many fish recovered; lobsters did not, partly because the water has grown warmer.

California connection: changing nets to cut by-catch

Swordfish off California were long caught with large-mesh drift gillnets, set at dusk and left to drift all night. Along with swordfish, the nets tangled sea turtles, dolphins, whales and sharks.

- **2018:** a California law paid fishers to give up drift gillnets and ended state permits by 2024.

- **December 2022:** a federal law began a five-year phase-out of large-mesh drift gillnets.

- **2023:** NOAA approved deep-set buoy gear: baited hooks set deep by day and watched by the crew.

Swordfish feed deep in the daytime, where few turtles or dolphins are, so by-catch drops.





THINK, PAIR, SHARE

Discuss: should a farming district get rid of its bats?

- Sort your questions into two columns: science can predict / people must decide.
- Example: 'Would chasing the bats away lower the risk or just move it?' Which column?
- Example: 'Should pig farmers or the whole district pay for new sheds?' Which column?

Fruit bats near pig farms can carry Nipah virus, but they also pollinate fruit trees and spread forest seeds. Which questions about protecting farmworkers can science answer, and which can only the community answer?

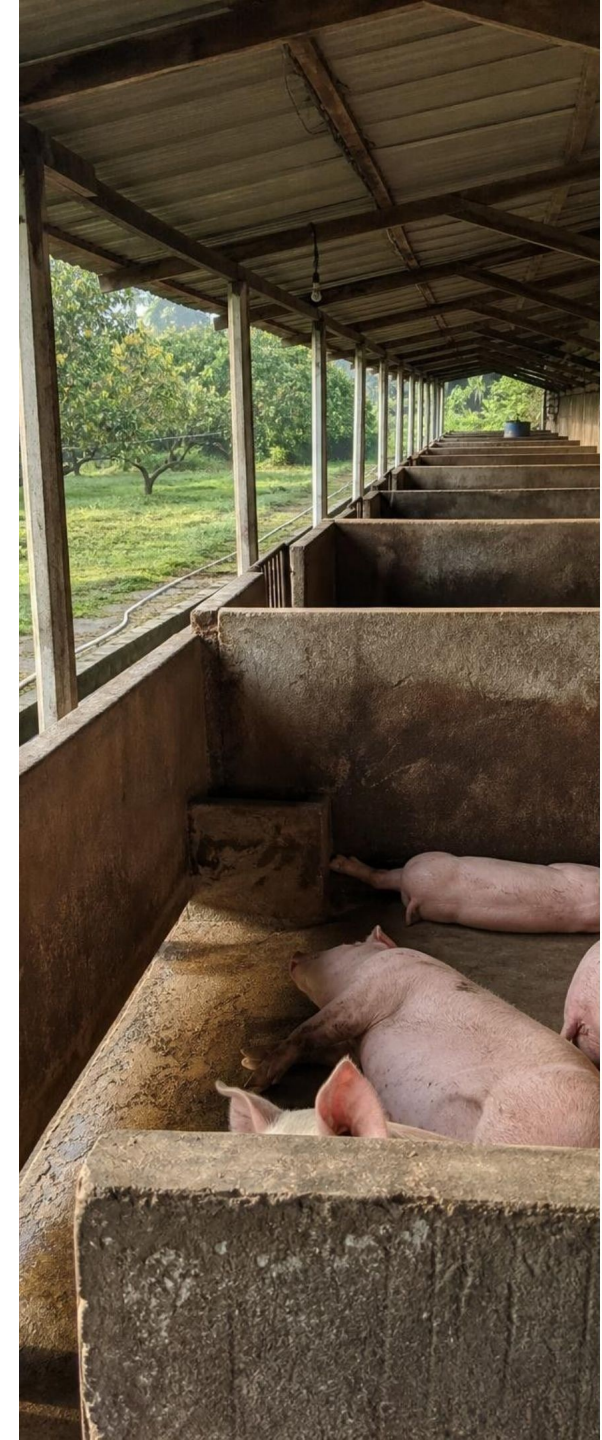
Apply it

Task: score three Nipah plans with a weighted matrix

Simulated data for practice.

Criterion (weight)	Move pig pens away	Bat-proof the sheds	Remove the bat roost
Human health (3)	4	3	2
Bats and their services (2)	4	4	0
Farm income (1)	3	4	1
Low cost (1)	1	2	4
Weighted total	?	?	?

Multiply each score by its weight and add down each column. Which plan wins? Then raise the farm-income weight from 1 to 3. Does the winner change?



CHECK FOR UNDERSTANDING

Quick check: what can science decide?

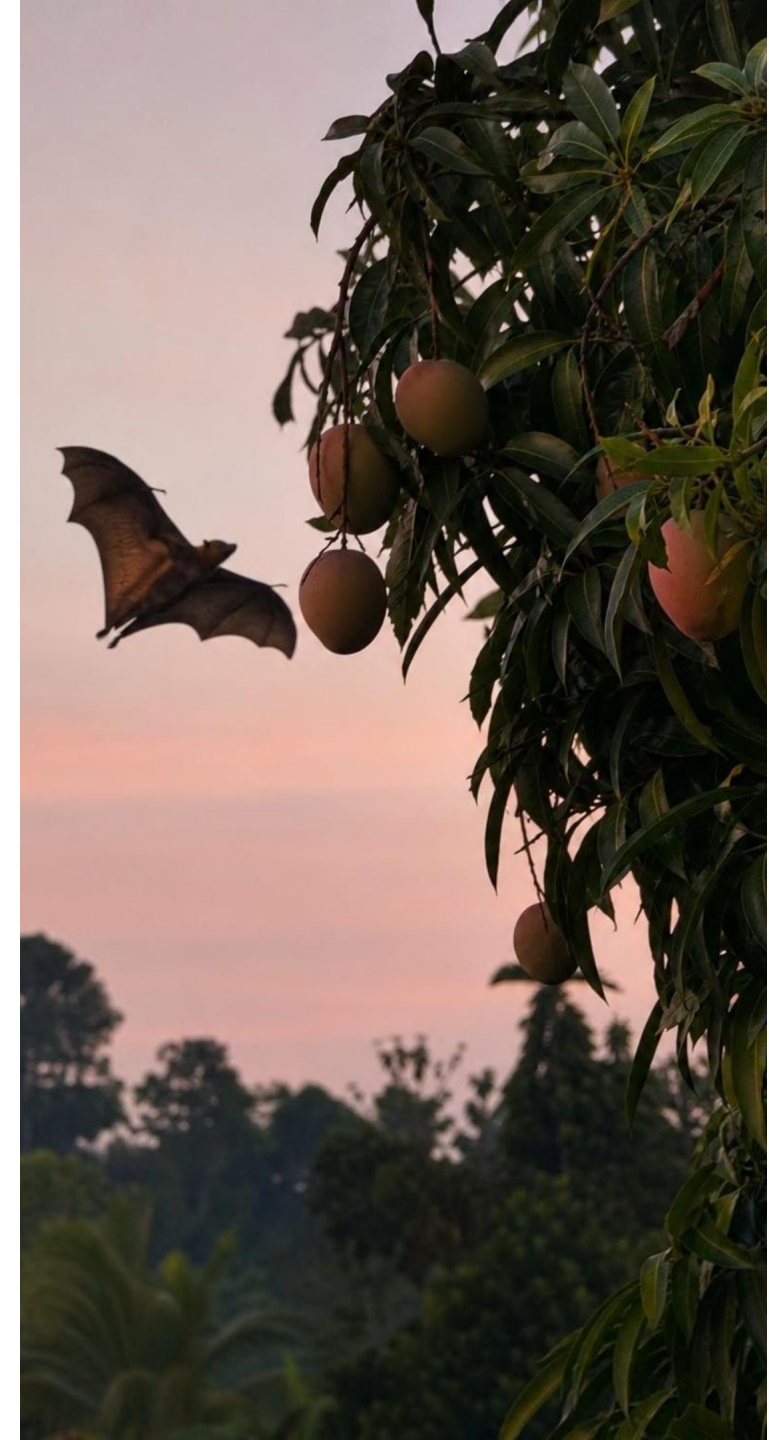
Which statement about the Nipah decision is accurate?

A. Science predicts what each plan will do; people decide how much each result matters.

B. Science can tell the town which plan is best.

C. A weighted matrix removes opinions from the decision.

D. The plan with the top score has no tradeoffs.





MISCONCEPTION CHECK

True or false? Stop growth and impact stops growing

"If the world's population stopped growing tomorrow, humans' impact on ecosystems would stop growing too."

True or false? Explain your reasoning.

PUTTING IT TOGETHER

Putting it together

- Wild populations rise and fall with the food their own ecosystem makes; people draw on the whole planet.
- Demand on ecosystems = number of people × use per person, shaped by the technologies we choose.
- Disruptions travel along cause-and-effect chains and often loop back to people.
- Good solutions start with precise criteria and constraints, then get tested and revised.
- Choosing among solutions takes data and values: science predicts, communities decide.





EXIT TICKET

Exit ticket

1. A city of 50,000 people uses 10,000,000 liters of water a day. Find the per capita use.
2. Give one reason the lynx population falls but the human population has not.
3. A net keeps 27 of 30 big fish and lets 48 of 60 small fish escape. Did it reach 80 percent on both?