

What Sets the Limit? A Twelve-Ecosystem Evidence Jigsaw

Learning target: I can work with a team to sort evidence from many ecosystems by what limits or shapes the organisms there, find the patterns that repeat on land and in water, and use them to predict what limits life in a new place.

Collaborative investigation

About 50 min

Jigsaw

MS-LS2-2 · practice

MS-LS2-1 · practice

collaboration

discussion

reading

Standards connections

MS-LS2-2 (practice, the competition pattern and the resource patterns across ecosystems): Teams compare competition in a rocky shore, a savanna and a culture tube, and compare what limits life in deserts, forests, lakes and reefs, then predict the same pattern in a new ecosystem (California coastal upwelling). Predator and partner interactions come in Lesson 21, so this builds toward the PE rather than assessing it.

MS-LS2-1 (practice, evidence for effects of resources on individual organisms and on population size): The cards are qualitative summaries of real research, and several show a resource changing population size (wildflowers, woodpeckers, algae) or individual bodies (urchins, flamingos). Students interpret this evidence but do not analyze numerical data, so the sheet is practice for the PE.

Purpose: practice · **Time:** about 50 minutes · **Format:** jigsaw

Answers with reasoning

Twelve evidence cards from real ecosystems (teacher cuts these apart)

1 Card 1: Desert wildflowers after a wet winter

In the Colorado Desert of southern California, the seeds of annual wildflowers can wait in the soil for years. After a winter with soaking rains spread over several weeks, millions sprout at nearly the same time and whole hillsides turn orange, purple and yellow; Anza-Borrego Desert State Park had famous blooms like this in 2017 and 2019. After a dry winter, only a scattered few come up, even though the sunlight and the soil are the same.

2 Card 2: Coast redwoods and summer fog

Coast redwoods grow naturally only in a narrow strip along the Pacific coast, from the southwest corner of Oregon to southern Monterey County in California. Summers there bring almost no rain, but fog rolls in off the ocean on many days. Fog droplets collect on the needles and drip to the ground, and the trees can also take some fog water in directly through their needles. Researchers measuring one redwood forest found that fog drip supplied about a third of all the water the ground received in a year.

3 Card 3: Treeline in the high Sierra Nevada

On the highest slopes of the Sierra Nevada, forests thin out and stop at a line called the treeline. Above it, snowmelt keeps parts of the soil wet and summer sunlight is strong, yet no trees grow, only low grasses, cushion plants and wildflowers. The growing season there lasts only about two months, and nights can freeze even in July. Scientists who compare treelines around the world find that they sit where the growing season is too cold for trees to build new wood.

4 Card 4: How deep can a lake plant grow?

In a clear mountain lake, rooted water plants and bottom-dwelling algae can grow many meters down, because enough sunlight reaches the lake floor. In a muddy lake, where stirred-up silt clouds the water, the same kinds of rooted plants grow only in a narrow band of shallow water near the shore. In both lakes the plants have water all around them and nutrients in the mud.

5 Card 5: Fertilizer and a green lake

After heavy spring rains wash fertilizer from farm fields into a lake, the water can turn pea-soup green within a few weeks as algae multiply into a bloom. Fertilizer adds nitrogen and phosphorus, nutrients the algae need. When the bloom dies, bacteria that break down the dead algae use up much of the oxygen dissolved in the deeper water, and fish living there can die.

6 Card 6: Coral reefs in shallow, clear, warm water

Reef-building corals have single-celled algae living inside their tissues. The algae make food from sunlight and share much of it with the coral. Coral reefs grow mostly in shallow, clear, warm tropical seas, and mud washed from the land that clouds the water slows their growth. When the water stays a degree or two hotter than its usual summer maximum for several weeks, the corals expel their algae and turn white, which is called bleaching. If the heat lasts, many of the corals die.

7 Card 7: Two barnacles, one rocky shore

On a rocky shore in Scotland, two barnacle species live attached to the rocks. One lives high on the shore, where the falling tide leaves the rocks dry for hours; the other lives lower down. Young barnacles of the upper species also settle on the lower rocks, but there the lower species grows faster and crowds them out, smothering, undercutting and crushing them. When an ecologist scraped the lower species off some rocks, the upper species survived lower on the shore.

8 Card 8: Zebras and wildebeest on the Serengeti

On the Serengeti plains of East Africa, huge herds of zebras and wildebeest graze the same grasslands. Zebras tend to eat the taller, tougher grass stems, while wildebeest tend to eat the shorter, leafier grass, and herds often move across the plains with zebras ahead and wildebeest following. In the dry season, when grass is short and scarce everywhere, both herds must travel long distances to find enough to eat.

9 Card 9: Two kinds of Paramecium in one tube

In the 1930s the Soviet biologist Georgy Gause grew two species of Paramecium, single-celled organisms that eat bacteria. Grown in separate tubes, each given the same small amount of food every day, each species increased and then leveled off. Grown together in one tube with that same daily food, one species grew and held its numbers while the other declined until it disappeared from the tube.

10 Card 10: Acorn woodpeckers in a lean year

Acorn woodpeckers in California's oak woodlands live in family groups that store thousands of acorns in holes drilled into a 'granary' tree, then eat them through the winter and spring. Researchers in Carmel Valley have followed these groups for decades. In years when the oaks produce few acorns, many groups skip nesting and fewer young are raised; after a big acorn year, more groups breed and the population grows.

11 Card 11: Starving urchins on bare rock

Off the coast of Northern California, bull kelp forests shrank sharply after 2014, when a marine heat wave and a disease that killed most of the sea stars that eat urchins struck at about the same time. Purple sea urchins multiplied and ate much of the remaining kelp, leaving stretches of bare rock called urchin barrens. Urchins in a barren survive by scraping thin films off the rock, but they are starving: they hold very little of the egg-making tissue that fills a well-fed urchin in a kelp forest.

12 Card 12: Why flamingos are pink

Flamingos are pink because of red and orange pigments called carotenoids in the algae and tiny shrimp they eat; the birds deposit the pigment in their feathers as the feathers grow. Flamingo chicks are gray. In zoos, flamingos fed a diet with no carotenoids grow pale, nearly white feathers, so zoo keepers add carotenoids to their food.

Three questions for every card — (1) **What limits or shapes the organisms?** Name one specific thing. (2) **Is it a resource or a condition?** A resource is taken in or used up, so there is less for others (food, water, light, nutrients, space). A condition affects organisms but is not used up (temperature, how salty or acidic the water is). If it is a resource, is it biotic (living or from living things) or abiotic? (3) **What does it change?** Where a species can live, how many individuals there are, or the bodies of individuals (their growth, color or health).

Part A: Expert round (one set per person)

1. Your expert set: _____. For each of your three cards, answer the three questions in the box above, and copy the one sentence from the card that is the best evidence for your answer to question 1. Then write one sentence that says what your three cards have in common.

Answer: Set A (land): Card 1, water from winter rain; abiotic resource; changes how many plants sprout and bloom (population size); evidence: 'After a dry winter, only a scattered few come up, even though the sunlight and the soil are the same.' Card 2, water from fog drip during rainless summers; abiotic resource; changes where redwoods can live (a narrow foggy coastal strip); evidence: fog drip supplied about a third of the ground's yearly water. Card 3, a short, cold growing season; condition (temperature), not a resource, since water and light are present; changes where trees can live; evidence: 'they sit where the growing season is too cold for trees to build new wood.' Common thread: on land, water and temperature decide where and how many plants grow. Set B (water): Card 4, light; abiotic resource; changes where rooted plants can live (how deep); Card 5, nitrogen and phosphorus; abiotic resources; changes how many algae (a bloom), and then oxygen, another resource, is used up for fish; Card 6, light for the corals' algae (abiotic resource) plus water temperature (condition); changes where reefs grow and whether corals survive. Common thread: in water, light and nutrients are the usual limits. Set C (two species): Card 7, space on the rock; abiotic resource; between species; changes where the upper species can live; Card 8, grass; biotic resource; between species, eased by eating different parts of the grass; changes how far herds must travel and how many can be fed in the dry season; Card 9, bacteria as food; biotic resource; between species; one species disappears from the tube (population size). Common thread: when two species need the same limited resource, one may be pushed out unless they use it differently. Set D (individuals): Card 10, acorns; biotic resource; changes how many young are raised (population); Card 11, kelp; biotic resource; changes individual bodies (starving urchins with little egg-making tissue), and therefore future numbers; Card 12, carotenoid pigments in food; biotic resource (the pigment comes from algae and shrimp); changes individual bodies (feather color). Common thread: a food resource can change individual bodies as well as numbers.

Why: Each expert answers for their own set only; the key lists all four sets so the teacher can check any student. The evidence sentence should be the one that isolates the factor (for example, card 1's 'even though the sunlight and the soil are the same').

Also acceptable: Card 2 may be described as limiting how many redwoods grow as well as where; card 11 may be described as changing the population (fewer eggs) as well as bodies. Card 8 may be listed as 'not shown' for competition if the student explains that the different feeding styles reduce it; push for 'between species, reduced.'

- All three cards in the set answered for factor, resource or condition, and what it changes
- One accurate evidence sentence per card
- A common-thread sentence that fits all three cards

Part B: Home group task

1. Each expert teaches their three cards in two minutes or less, reading the evidence sentence aloud.
2. As a group, fill in one row of the group record for each card. If the group disagrees about a row, write both answers and the reason for each.
3. Lay the twelve cards in two piles: cards where a **resource** is the main story and cards where a **condition** matters. Some cards belong in both piles; place them between the piles.
4. Answer q2, q3 and q4 together. Write the group's answer, not just one person's.
5. Choose one member to explain the q2 rule to the class; your teacher may call on any member instead.

Group record (fill in)

Card	What limits or shapes the organisms?	Resource (biotic or abiotic) or condition?	What it changes: where they live, how many, or individual bodies	Competition shown? (within a species, between species, or not shown)
Card 1				
Card 2				
Card 3				
Card 4				
Card 5				
Card 6				
Card 7				
Card 8				
Card 9				
Card 10				
Card 11				
Card 12				

2. Group answer: Write a two-part rule that predicts what usually limits plant and algae growth **on land** and **in water**. Support each part with two cards. Then name the card that does not fit either part of your rule neatly, and explain why.

Answer: Rule: on land, water (and how cold or warm it is) usually decides how many plants grow and where; in water, light and nutrients usually decide it. Land support: card 1 (rain decides how many wildflowers sprout) and card 2 (fog water decides where redwoods grow); card 3 adds that temperature can rule out trees even where water and light are present. Water support: card 4 (light decides how deep plants grow) and card 5 (nutrients decide how many algae grow); card 6 also fits (light). The card that fits neither part neatly is card 3 on land, because it is limited by a condition (cold) rather than by water, or card 6 in water, because temperature matters there too. Cards 7-12 are about animals, single-celled organisms or competition rather than plant growth, so they test other ideas.

Why: This is the cross-ecosystem pattern the chapter builds toward: water and temperature on land, light and nutrients in water. Any honest exception, explained, earns credit.

Also acceptable: A group that writes 'whatever is in shortest supply compared with what the organism needs' as a single rule and then shows which resource that is on land and in water has written a stronger rule; give full credit.

- Two-part rule: water (and temperature) on land; light and nutrients in water
- Two supporting cards for each part
- Names an exception (card 3 or card 6 is expected) and explains it with resource versus condition

3. Group answer: Cards 7, 8 and 9 all show competition between species. For each card, name the shared resource. Then explain why the competitors on two of the cards could not keep living in the same place, while the competitors on the third card could.

Answer: Card 7: space on the rock. Card 8: grass. Card 9: bacteria (food). On cards 7 and 9 the two species used the resource in the same way, so the stronger competitor took nearly all of it: the lower barnacle crowded the upper species off the low rocks, and one Paramecium species disappeared from the shared tube. On card 8 the zebras and wildebeest eat different parts of the grass (taller, tougher stems versus shorter, leafier grass), so they overlap less, compete less, and can share the plains, although both still struggle when grass is scarce in the dry season.

Why: The same pattern as the yaks and horses: species that need the same limited resource compete, and using it in different ways reduces competition and allows coexistence.

Also acceptable: Accept 'the upper barnacle can still live higher up, where the lower species cannot survive drying out' as a fuller account of card 7.

- Names space, grass and bacteria correctly
- Explains exclusion on cards 7 and 9 as using the same resource in the same way
- Explains coexistence on card 8 by different use of the resource
- Notes that competition still happens when the resource is scarce

4. Group answer: Card 6 involves both a resource and a condition. Name each one, and explain why you need both to explain where coral reefs grow. Then find one other card that involves both, and name its resource and its condition.

Answer: Card 6: the resource is sunlight (used by the algae inside the corals to make food); the condition is water temperature. Light explains why reefs grow in shallow, clear water; temperature explains why they grow only in warm seas and why a few weeks of unusually hot water can kill them. Neither alone explains both the depth limit and the latitude and heat limits. Another card with both: card 3 (water from snowmelt and sunlight are resources, while cold is the condition that stops the trees) or card 5 (nutrients and oxygen are resources; the condition is not stated, so card 3 is the stronger choice).

Why: Students must keep resource and condition separate even when both act on the same organisms.

Also acceptable: Accept 'mud blocks light' as part of the light explanation.

- Light named as the resource and temperature as the condition for card 6
- Explains what each one accounts for
- Names a second card and correctly separates its resource from its condition

Part C: Individual accountability (complete alone)

A new ecosystem. Along the California coast in spring and summer, steady winds push surface water away from the shore, and cold water rises from the deep to replace it. This rising deep water, called upwelling, carries nitrogen and other nutrients that have built up in the deep, dark water. Sunlight is strong at the surface both near shore and far out at sea. Where upwelling is strong, phytoplankton (drifting, single-celled algae) multiply, small fish such as anchovies that eat them grow plentiful, and seabirds and sea lions feed on the anchovies. In some years the winds are weak and little deep water rises.

5. In the upwelling story, what is the limiting resource for the phytoplankton? Say whether it is biotic or abiotic, explain why sunlight is **not** the limiting resource here, and name the card that works most like this one.

Answer: The limiting resource is nutrients (nitrogen) brought up by the deep water, an abiotic resource. Sunlight is not limiting because it is strong at the surface both where upwelling happens and where it does not, yet phytoplankton multiply only where the nutrients arrive. The most similar card is card 5, where added nitrogen and phosphorus caused an algae bloom.

Why: The comparison between strong and weak upwelling holds light constant, which is the same logic as card 1 (rain differs, sunlight and soil the same).

Also acceptable: Accept card 4 only if the student explains it as 'a resource that decides where algae can grow' and still names nutrients, not light, for upwelling.

- Nutrients (nitrogen) named
- Abiotic
- Explains that light is present in both places, so it is not what differs
- Names card 5

6. Predict what happens to the phytoplankton, the anchovies and seabird chicks in a year when upwelling is weak. Trace the chain of causes, and say whether the effect on the chicks would show up in their **numbers**, their **bodies**, or both.

Answer: With weak upwelling, fewer nutrients reach the sunlit surface, so fewer phytoplankton grow. With less phytoplankton, fewer anchovies are fed, so the anchovy population falls or moves elsewhere. Seabird parents find fewer anchovies to bring to their chicks, so chicks grow more slowly and weigh less (their bodies), and fewer chicks survive to leave the nest (their numbers). So the effect shows up in both.

Why: The chain is nutrients → phytoplankton → anchovies → seabird chicks, the same resource chain as rain → grass → grazers. Card 10 (lean acorn years, fewer young) and card 11 (starving urchins) are the models for numbers and bodies.

Also acceptable: A student who adds that adult seabirds may not nest at all in a very poor year, as in card 10, is applying the cards well.

- Chain traced through phytoplankton and anchovies to the chicks
- Effect on chick bodies (growth, weight) and on numbers (survival)
- Each link explained as a resource for the next

7. Cards 3 and 4 both describe a line beyond which plants stop growing. Explain why one line is set by a condition and the other by a resource.

Answer: Card 3's treeline is set by a condition: the growing season is too cold for trees to build new wood, even though water and sunlight are present, and cold is not something trees use up. Card 4's depth line is set by a resource: light, which the plants take in to make food and which runs short with depth, especially in muddy water.

Why: The pair contrasts a condition and a resource that both create a sharp edge to where plants can live.

Also acceptable: Accept 'cold growing season' or 'temperature' for card 3.

- Card 3 = condition (temperature) with a reason
- Card 4 = resource (light) with a reason

8. Card 12 and the poison dart frogs from earlier in this chapter tell the same kind of story, while card 10 tells a different kind. Explain what kind of story each one is, using the words **resource**, **organism** and **population**.

Answer: Card 12 and the dart frogs are stories about individual organisms: a specific resource in the food (carotenoid pigments for flamingos, alkaloids from prey for the frogs) changes what each organism's body is like, its color or its poison, and an animal that does not get that resource lacks the trait even though it has plenty of other food. Card 10 is a population story: the amount of a food resource (acorns) changes how many young are raised, so a scarce resource means fewer woodpeckers and an abundant one means the population grows.

Why: MS-LS2-1 asks about effects of resources on organisms and on populations; this item checks that students can tell the two kinds of effect apart.

Also acceptable: A student who notes that individual effects can lead to population effects (starving urchins make few eggs) has connected the two; give full credit.

- Card 12 and frogs identified as resource effects on individual organisms (traits or bodies)
- Card 10 identified as a resource effect on population size (reproduction)
- Uses resource, organism and population correctly

Scoring rubric

Criterion	4 • Exemplary	3 • Proficient	2 • Developing	1 • Beginning
Group record and sorting	All twelve rows complete and accurate: the factor is specific, temperature and cold are classed as conditions, biotic and abiotic resources are labeled correctly, and the 'what it changes' and competition columns match the cards.	Ten or eleven rows accurate; one or two rows vague or with one wrong label.	Several rows incomplete or mislabeled, or temperature classed as a resource.	Record mostly blank or copied from the cards without classifying.
Pattern across ecosystems (q2 and q4)	States the land and water rule, supports each part with two correct cards, explains an exception, and separates resource from condition on card 6 and a second card.	Rule and support are correct, but the exception or the second resource-condition card is missing or weakly explained.	Rule is partly correct or supported by only one card per part.	No rule, or a rule that contradicts the cards.
Competition analysis (q3)	Names the shared resource on all three cards and explains exclusion versus coexistence by how the resource is used, noting that competition remains when the resource is scarce.	Names the three resources and explains the difference, but omits that the card 8 competitors still compete.	Names the resources but does not explain why the outcomes differ.	Describes competition as fighting or does not name the resources.
Individual accountability (Part C)	All four answers accurate: names nutrients for upwelling with the light comparison, traces the chain to chick bodies and numbers, contrasts condition and resource on cards 3 and 4, and separates organism and population stories.	Three of four accurate with reasoning; one thin or partly incorrect.	Two accurate; others restate the group record without reasoning.	Part C mostly blank or inaccurate.

Teacher notes

Every card summarizes real, published work, stated without invented numbers. Card 1: desert annuals germinate in large numbers after well-timed winter rains; Anza-Borrego's widely reported blooms were in 2017 and 2019. Card 2: the coast redwood's natural range runs from southwestern Oregon to southern Monterey County; Todd Dawson's 1998 study in a northern California redwood forest measured fog drip as about a third of annual water input, and later work showed redwood needles absorb fog water. Fog is one reason the range hugs the coast, but frost, soils and history matter too, so do not let students claim fog alone sets the range. Card 3: global comparisons of treelines (Christian Körner and colleagues) place them where growing-season temperatures are too low for wood growth, not where water or carbon run out. Card 5: nutrient runoff, algal blooms and low-oxygen fish kills are standard eutrophication. Card 6: coral bleaching typically follows several weeks at about 1 °C or more above the usual summer maximum. Card 7: Joseph Connell's barnacle removal experiments on the Isle of Cumbrae, Scotland (published 1961). Card 8: the zebra-wildebeest grazing sequence described by Richard Bell and others in the Serengeti; keep the claim at 'tend to eat'. Card 9: G. F. Gause's 1934 *Paramecium aurelia* and *P. caudatum* cultures. Card 10: the long-term acorn woodpecker study at Hastings Reservation in upper Carmel Valley (Walter Koenig, Ronald

Mumme and colleagues). Card 11: the post-2014 loss of most northern California bull kelp after sea star wasting disease and the 2014-2016 marine heat wave; barren urchins have very small gonads. Card 12: flamingo coloration comes from dietary carotenoids, and zoos supplement them. Run the expert round with a timer; experts who finish early should rehearse the two-minute teach. The most common disputes are card 3 (students call cold a 'lack of the resource heat'; hold firm that temperature is a condition) and card 8 (students say 'no competition'; the different feeding styles reduce it, they do not remove it). Part C is the individual evidence; grade it separately from the group record.

Scaffold offered to students: Sentence starters for experts and teachers

Use these when you teach your cards: 'On this card, the organisms are _____. The thing that limits or shapes them is _____. It is a (resource / condition) because _____. The evidence sentence is _____. It changes (where they live / how many there are / their bodies).'

If you are stuck on resource versus condition, ask: 'If one organism uses it, is there less left for the next one?' If yes, it is a resource.

Extension: Write card 13

Research one California ecosystem not on the cards (for example a vernal pool, a desert spring, Mono Lake, or a chaparral slope after a fire) and write a thirteenth card in the same style: four or five sentences, real facts only, and no answer given away. Then write the group-record row for your card on the back, and name one source you used. Trade cards with another group and check whether they fill in the row the way you intended.