

If One Partner Changes: A Jigsaw on Interaction Rules

Learning target: I can work with a team to classify real interactions from evidence, write rules that predict what happens to one partner when the other partner's population changes, and apply those rules to an ecosystem none of us has studied.

Collaborative investigation

About 50 min

Jigsaw

MS-LS2-2 · practice

collaboration

discussion

writing

Standards connections

MS-LS2-2 (practice, deriving prediction rules from cases in many ecosystems and applying them to a new one): The twelve cards come from oceans, islands, deserts, forests, grasslands and pastures. Teams turn them into one set of rules for how each interaction type moves populations, then use the rules to predict changes in an unfamiliar mountain ecosystem. That builds the explanation-that-predicts the PE asks for; students are assessed on it individually in W6 and W9.

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

Answers with reasoning

Twelve evidence cards: what happened when one partner changed

1 Card 1 (Set A): Sea otters, urchins and kelp, California coast

Sea otters dive for purple sea urchins and eat them. The urchins graze giant kelp. Fur hunters killed nearly all of California's sea otters by the early 1900s. On reefs where the otters were gone, urchins multiplied and chewed the kelp down to bare rock. A small group of otters survived along the Big Sur coast; as it spread, urchins became scarce on those reefs and kelp forests grew back.

2 Card 2 (Set A): Wolves and moose, Isle Royale

On Isle Royale, an island in Lake Superior, wolves are the moose's only large predator, and moose are most of the wolves' food. Over sixty years of counts, wolf numbers often rose a few years after moose numbers rose and fell a few years after moose numbers fell, though disease and hard winters also moved both lines. When disease and inbreeding left only two wolves in the late 2010s, the moose population grew quickly.

3 Card 3 (Set A): Deer and young oaks, oak woodland

Deer browse the leaves and shoots of young oak trees, usually without killing them. Ecologists in many oak woodlands have fenced small plots so that deer cannot enter. After several years, fenced plots hold far more young oaks tall enough to escape browsing than unfenced plots nearby, where the young oaks stay short and are bitten back every year.

4 Card 4 (Set B): Yucca and yucca moth, southwestern deserts

A female yucca moth gathers pollen from one yucca flower, flies to another, lays her eggs inside its seed chamber and presses pollen onto the flower so that seeds form. Her caterpillars eat some of the seeds and leave the rest. The moth caterpillars eat nothing but yucca seeds, and no other insect pollinates these yuccas. Yuccas planted in gardens on other continents flower but set no seed unless people pollinate them by hand.

5 Card 5 (Set B): Figs and fig wasps, warm regions worldwide

Each kind of fig tree is pollinated by its own kind of tiny wasp. A female wasp crawls into a young fig, which is really a closed cluster of flowers, pollinates the flowers and lays eggs in some of them. Her young grow up inside, eating a few developing seeds, and the new females fly off carrying pollen. In the 1880s and 1890s, California farmers planted a Turkish fig whose young fruit kept dropping off; the crop succeeded only after its wasp was brought from the Mediterranean and settled in 1899.

6 Card 6 (Set B): California poppies and their many visitors, grassland

California poppies are visited by many different kinds of bees, beetles and flies. Each visitor gets pollen or a place to rest in the warm flower and carries some pollen to the next poppy. Ecologists find that a flower served by many kinds of visitors usually keeps setting seed when one kind of visitor becomes rare, because the others fill in. A flower that depends on a single kind of visitor is hit much harder.

7 Card 7 (Set C): Winter ticks and moose, New England forests

Winter ticks climb onto moose in autumn and drink their blood all winter; one moose can carry tens of thousands. In years when autumn is long and snow comes late, tick numbers boom, and many moose calves are too weakened by blood loss to survive until spring. In years with fewer ticks, more calves survive. Each winter tick spends its whole feeding life on a single large mammal, such as a moose, deer or elk, and cannot develop without one.

8 Card 8 (Set C): Gray whales and gray whale barnacles, Pacific Ocean

One kind of barnacle settles only on the skin of gray whales and nowhere else. The adult barnacles filter tiny food from the water as the whale swims along its migration route. Scientists have not measured any harm or benefit to the whales from carrying them. Because the barnacle lives on no other surface, the number of places it can live depends on how many gray whales there are.

9 Card 9 (Set C): Cattle egrets and grazing animals, pastures

Cattle egrets are small white herons that walk beside grazing cattle, horses and wild grazers, catching grasshoppers and other insects that the grazers' feet flush from the grass. Egrets feeding beside grazers catch more food with fewer steps than egrets feeding alone. The grazers show no measured gain or loss. Over the last 150 years, as cattle ranching spread, cattle egrets spread from Africa to the Americas, including California, and became common wherever there were pastures.

10 Card 10 (Set D): Barred owls and spotted owls, Pacific Northwest and northern California forests

Barred owls spread west from eastern North America during the 1900s and now share old forests with northern spotted owls. Both hunt flying squirrels, woodrats and other small mammals, and both need big trees with nest sites; the larger barred owls drive spotted owls out of their territories. In a large experiment, barred owls were removed from some study areas. Spotted owls there nearly stopped declining, while in comparison areas where barred owls stayed, spotted owls kept declining.

11 Card 11 (Set D): Starlings and bluebirds, parks and farmland

European starlings, released in New York in 1890, spread across North America. They nest in tree holes, as bluebirds do, and there are only so many holes; starlings are larger and take over many of them, and both species spend time and energy fighting for holes. Volunteers have put up thousands of bluebird nest boxes with entrance holes too small for a starling. Along these 'bluebird trails', bluebird numbers rose.

12 Card 12 (Set D): Yellow starthistle and native plants, California grassland

Yellow starthistle, a spiny weed from the Mediterranean, now covers millions of acres of California grassland. Its deep roots use up soil water in summer, leaving less for native grasses and wildflowers growing in the same soil. Where land managers have controlled starthistle, more water stays in the soil and native plants can increase. Where native perennial grasses are thick, starthistle seedlings have a harder time getting started.

Part A: Expert round (one set per person)

1. Your expert set: _____. For each of your three cards, name the two main partners, rate the effect on each (+, – or 0) and name the interaction. Then write one sentence describing what happened to one partner when the other partner's numbers changed.

Answer: Set A: card 1, otter + and urchin – (predation), and urchin + and kelp – (predation, an herbivore in this lesson); with otters gone, urchins rose and kelp fell. Card 2, wolf + and moose – (predation); when wolves fell to two, moose rose; wolf numbers followed moose numbers with a delay. Card 3, deer + and oak – (predation in this lesson's broad sense); when deer were fenced out, young oaks increased. Set B: card 4, yucca + and moth + (mutualism); without the moth, yuccas set no seed. Card 5, fig + and wasp + (mutualism); without the wasp the fig crop failed. Card 6, poppy + and each visitor + (mutualism); when one visitor becomes rare, the poppy usually keeps setting seed because others fill in. Set C: card 7, tick + and moose – (parasitism); more ticks, fewer calves survive; the tick needs a living host. Card 8, barnacle + and whale 0 (commensalism); no harm or benefit to the whale has been measured; barnacle living space depends on whale numbers. Card 9, egret + and grazer 0 (commensalism); as cattle spread, egrets spread. Set D: card 10, barred owl – and spotted owl – (competition); removing barred owls nearly stopped the spotted owl decline. Card 11, starling – and bluebird – (competition); giving bluebirds starling-proof holes raised bluebird numbers. Card 12, starthistle – and native plants – (competition); controlling starthistle lets native plants increase.

Why: Each card states both partners' outcomes and one population change, so the codes and the 'what happened' sentence can be read from the card without outside knowledge.

Also acceptable: On card 1, a student who rates only the otter-urchin pair is acceptable. On card 11 or 12, accept a student who rates the winner '– (gets less than it would alone)' with that reason; a student who rates the winner + should be redirected to the definition.

- Correct partners and codes for all three cards in the set
- Correct interaction name for each
- A population change stated for at least one card

Part B: Home group task

1. Each expert teaches the group their three cards in two minutes or less: the partners, the codes, and what happened when one partner changed.
2. Together, fill in one row of the rule table for each interaction type. Every rule must name at least one card as its evidence.

3. Check each rule against the cards from the other sets. If a card breaks a rule, rewrite the rule (card 6 is a good test for the mutualism row).
4. Read the four Granite Basin change cards. For each one, decide which interaction is involved, then use your rules to predict what happens.
5. Before Part C, make sure every member can explain one rule and one Granite Basin prediction without notes.

2. Group answer: complete the rule table.

Answer: Predation (+ –): if the predator becomes scarce, the prey usually increases, and can then overeat its own food (cards 1, 2, 3); if the prey becomes scarce, the predator usually decreases after a delay (card 2). Parasitism (+ –): if the parasite becomes scarce, the host usually becomes healthier and its numbers can rise (card 7, more calves survive in low-tick years); if the host becomes scarce, the parasite decreases because it cannot develop without a host (card 7). Commensalism (+ 0): if the commensal becomes scarce, the host shows little or no change (cards 8, 9); if the host becomes scarce, the commensal decreases, and if the host increases, the commensal can increase (cards 8, 9). Mutualism (+ +): if either partner becomes scarce, the other usually decreases, strongly when the two depend only on each other (cards 4, 5) and only a little when a partner has many substitutes (card 6). Competition (– –): if either competitor becomes scarce, the other usually increases because more of the shared resource is left (cards 10, 11, 12).

Why: These are the population consequences that follow from each code. The mutualism row is the one most likely to need rewriting after the card 6 check, because many mutualisms are not one-to-one.

Also acceptable: Accept 'prey goes up, then crashes when food runs out' in the predation row. Accept 'parasite load falls' for the host-scarce parasitism cell.

- Correct code in every row
- Predation and competition directions correct
- Parasitism and commensalism rows show that the gainer depends on the other partner
- Commensalism row shows no effect on the host when the commensal changes
- Mutualism row is qualified by how many partners a species depends on
- At least one card cited per row

Granite Basin change cards (a high Sierra lake and meadow; teaching scenario) — Change 1. Trout stocked in the lake decades ago eat the tadpoles of mountain yellow-legged frogs. Managers remove every trout from the lake. **Change 2.** Clark's nutcrackers bury whitebark pine seeds in autumn and dig most of them up to eat later; the seeds they forget sprout into new pines, and pine seeds are the nutcrackers' main winter food. A disease kills many of the whitebark pines. **Change 3.** Two kinds of bumblebees gather nectar from the same few meadow flowers, and there is not enough nectar for both. A cold spring kills most of one kind. **Change 4.** Yosemite toads shelter from midday heat in the side tunnels of Belding's ground squirrel burrows; as far as scientists can tell, the squirrels are not affected. A disease kills most of the ground squirrels, and their burrows slowly collapse.

3. Group answer: predict the effect of each Granite Basin change.

Answer: Change 1: predation, trout + and frog tadpoles –; with the trout removed, the frog population should increase over the next few years (rule: predator scarce, prey increases). Change 2: mutualism, nutcracker + and pine +; with fewer pines, nutcrackers should decrease or leave, and with fewer nutcrackers burying seeds, fewer new pines sprout, so the pine decline can deepen (rule: one mutualist scarce, the other decreases). Change 3: competition, bee A – and bee B –; the surviving kind of bumblebee should increase, because more nectar is left for it (rule: one competitor scarce, the other increases). Change 4: commensalism, toad + and squirrel Ø; the toads should decrease or move, because their shelter disappears as burrows collapse (rule: host scarce, commensal decreases).

Why: Each change card states the interaction in words so groups classify it and then apply one rule from q2. Changes 1 and 2 are based on real Sierra Nevada cases: removing introduced trout from lakes has let mountain yellow-legged frogs recover, and nutcrackers have declined where whitebark pines died.

Also acceptable: In Change 2, accept 'nutcrackers switch to other conifer seeds, so they decline only a little' if the student explains it with the card 6 idea of substitutes. In Change 3, accept 'little change' only if the student argues the flowers were not limiting, which contradicts the card.

- Correct interaction and codes for each change
- Correct direction for the affected species
- A rule from the table named for each

Part C: Individual accountability (complete alone)

4. Explain the rule your expert set taught the group, using one card from your set as evidence. Include the interaction's code.

Answer: Depends on the expert set. Examples: Set A, predation (+ –): 'If a predator becomes scarce, its prey usually increases, as urchins did when otters were hunted out (card 1).' Set B, mutualism (+ +): 'If one partner disappears, the other declines when they depend only on each other, as yuccas set no seed without yucca moths (card 4).' Set C, parasitism (+ –) or commensalism (+ Ø): 'If ticks boom, moose calves die (card 7)', or 'If grazers spread, cattle egrets spread, but egrets do not change the grazers (card 9).' Set D, competition (– –): 'If one competitor is removed, the other increases, as spotted owls nearly stopped declining where barred owls were removed (card 10).'

Why: This checks that each student can carry their expert knowledge into the group's shared product.

Also acceptable: Any accurate rule from the student's set with card evidence.

- Rule stated as if-then
- Correct code
- A card from the student's set used as evidence

5. Fleas live in the fur and burrows of California ground squirrels in a park and drink the squirrels' blood. A dry year cuts the squirrel population in half. Predict what happens to the flea population over the next year, and name the interaction and the rule you used.

Answer: Parasitism (flea +, squirrel –). The flea population should fall over the next year, because fleas need living squirrels to feed on and to breed in their burrows; with half as many hosts there are fewer meals and fewer burrows, so fewer young fleas survive. Rule: if the host becomes scarce, the parasite decreases.

Why: The parasite depends on its host, so the parasitism rule from card 7 applies.

Also acceptable: A student who adds that fleas per squirrel may rise for a while as fleas crowd onto the remaining hosts, before the flea population falls, is reasoning carefully.

- Names parasitism with + –
- Predicts a decline in fleas
- Uses the host-scarce rule with a reason

6. The commensalism rule works in only one direction. Using the code + 0 and cards 8 and 9, explain why a change in the host matters to the commensal partner but a change in the commensal partner does not matter to the host.

Answer: In commensalism the commensal partner gets + and the host gets 0. Because the commensal depends on the host for food or a place to live, fewer hosts means fewer commensals: gray whale barnacles can live only on gray whales (card 8), and egrets spread as cattle spread (card 9). But the host gets nothing measurable from the commensal, so more or fewer commensals make no measurable difference to the host: no harm or benefit to gray whales from their barnacles has been measured (card 8).

Why: The zero is what makes the rule one-way: an effect that does not exist cannot be lost.

Also acceptable: A student who adds that the 0 means 'no measurable effect, as far as scientists can tell' is showing the chapter's accuracy point.

- Uses + 0 to explain the direction
- Evidence from card 8 or 9 for the host-to-commensal effect
- Explains why the commensal does not affect the host

7. The cards came from oceans, islands, deserts, forests, grasslands and pastures, and almost no species appeared twice. Explain why your group could still write one set of rules that works in all of them. Then use one rule to predict a change in an ecosystem none of the cards describes, such as a coral reef, the Arctic tundra or a city park: name the two partners (real or described in general terms), the interaction, the change and your prediction.

Answer: Model response: The species change from place to place, but the ways two species can affect each other do not. Every interaction gives each partner a +, – or 0, and the population consequences follow from those codes: a partner that gains (+) from another will decline if that other partner becomes scarce, and a partner that is harmed (–) will increase if the harmful partner becomes scarce. Because the cause and effect come from the codes and not from the particular species, the same rules worked for otters in the ocean, wolves on an island and owls in a forest. Prediction: on a coral reef, sharks and groupers eat smaller fish (predation, + –). If fishing removes most of the groupers, the small fish they eat should increase, and then the algae or animals those small fish eat should decrease.

Why: This is the core MS-LS2-2 reasoning: patterns of interaction are shared across ecosystems even though the species differ, so they support predictions in places not yet studied.

Also acceptable: Accept general partners such as 'a predator fish and its prey on a reef' or 'Arctic foxes and lemmings'. Accept a city-park example such as hawks and pigeons, or starlings and another hole-nester.

- Explains that the rules depend on the + – 0 codes, not on the species
- Refers to at least two different ecosystems from the cards
- Names two partners in a new ecosystem, the interaction, a change and a prediction that follows the rule

8. Rules can give wrong predictions. Using card 2 or card 6, describe one condition that makes a rule less reliable, and explain how a scientist should word a prediction because of it.

Answer: Card 2: disease and hard winters also moved the wolf and moose lines, so a rule built only on predation can be off in timing or size. Card 6: a mutualist with many partners hardly changes when one partner disappears, so the mutualism rule depends on how many substitutes exist. A scientist should therefore word a prediction as a likely direction ('usually', 'over the next few years') and name the conditions, instead of promising an exact amount or year.

Why: The rules describe patterns, not laws; the cards themselves show the limits.

Also acceptable: Accept other conditions with card evidence, such as predators with several prey species, or a third species entering the system.

- A condition from card 2 or card 6 that weakens a rule
- Explains how it changes the prediction
- Recommends cautious wording (direction, likely, conditions)

Scoring rubric

Criterion	4 • Exemplary	3 • Proficient	2 • Developing	1 • Beginning
Expert classification (Part A)	All three cards rated correctly for both partners and named, with the population change on each card stated accurately and taught clearly to the home group.	All three cards named correctly; one code or one population change is missing or slightly off.	One or two cards classified correctly; codes or changes confused on the others.	Cards not classified, or classified by where an organism lives rather than by effect.

Rule table (q2)	All five rows have correct codes and directions in both columns, each backed by a card, and the mutualism row is qualified by card 6.	All five rows mostly correct with card evidence; one cell is wrong or unsupported.	Three or four rows correct, or rows written without evidence cards.	Fewer than three rows correct, or rules contradict the cards.
Applying rules to Granite Basin (q3)	All four changes classified with codes, predicted in the correct direction and linked to a named rule; Change 2 notes the effect on the pines as well.	All four changes predicted correctly; one classification or rule link is missing.	Two or three changes predicted correctly, or predictions made without naming the interaction.	Predictions missing or contrary to the rules.
Individual accountability (Part C)	All five answers accurate and evidence-based; q7 explains why the rules work across ecosystems and makes a sound prediction for a new one.	Four answers accurate; q7 present but its explanation or its prediction is thin.	Two or three answers accurate; q7 restates a rule without explaining why it transfers.	Part C mostly blank or inaccurate.

Teacher notes

Print and cut the twelve cards and the Granite Basin callout. The expert sets are grouped by interaction type, but the cards do not name the type, so experts must classify before they generalize. All twelve cards describe real, documented cases, simplified: California sea otters were nearly wiped out by the fur trade and a remnant group off Big Sur later spread; Isle Royale wolves fell to two in 2016-2018 and moose increased (wolves were relocated to the island in 2018-2019); deer exclosures commonly show better oak regeneration; yucca and fig pollination are classic one-to-one mutualisms, and Smyrna-type figs in California needed the fig wasp established in 1899; winter tick epizootics have killed most moose calves in some New England years, and the winter tick is a one-host tick; the gray whale barnacle lives only on gray whales; cattle egrets spread to the Americas from the late 1800s; the barred owl removal experiment (Oregon, Washington and northern California, reported in 2021) found spotted owl declines nearly halted in removal areas; starling-proof nest boxes are standard for bluebird trails; yellow starthistle depletes summer soil water in California grasslands. Granite Basin is invented, but Changes 1 and 2 are based on real Sierra Nevada findings (frog recovery after trout removal; nutcracker declines with whitebark pine loss), while Changes 3 and 4 are plausible teaching cases. Lab 2 asks students to classify interaction cards into the plus-minus-zero grid; this sheet goes one step further, from the code to the population consequence, so it works well after Lab 2. The commensalism rule (q6) depends on the zero being real; remind students that zero means no measurable effect.

Scaffold offered to students: Start every card with two arrows

For each card, draw two boxes with the partners' names and two arrows between them. On the arrow from A to B, write what A does to B (+, – or 0); on the arrow back, write what B does to A. Then underline the sentence on the card that says what happened when one partner's numbers changed, and write 'up' or 'down' beside the other partner. Your rule is that sentence turned into an 'If..., then...' statement: 'If the predator becomes scarce, then the prey usually...'

Extension: A rule for three species

Card 1 links three species: otters eat urchins and urchins eat kelp. Write a rule for what happens to the kelp when the otters change, and test it against card 3 (what happens to young oaks when deer change) and Granite Basin Change 1 (what might happen to the insects the frogs eat when trout are removed). Explain why an effect that passes through a middle species can be harder to predict than a direct one, and name one thing that could stop the effect from reaching the third species.