

Did the Lupine Change the Pumice Plain? A Claim-Evidence-Reasoning Case

Learning target: I can construct a written argument, supported by evidence from repeated plot measurements, that the arrival of one population changed a physical component of an ecosystem and shifted other populations.

Claim, evidence, reasoning

About 45 min

Individual

MS-LS2-4 · assesses

MS-LS2-1 · supports

writing

data analysis

Standards connections

MS-LS2-4 (assesses, the full PE: an argument supported by empirical evidence that a change to a biological component (lupine arriving) affects other populations): Students write a complete claim-evidence-reasoning argument from repeated, comparative plot data, using a baseline year and a lupine-free comparison group to rule out another explanation. That is the argument from empirical evidence the PE asks for, and the rubric scores it directly.

MS-LS2-1 (supports): Usable nitrogen is the limiting resource in the reasoning: students explain the rise in seedlings as plant populations responding to a resource that lupine made more available, an idea from Lesson 20.

Purpose: assess · **Time:** about 45 minutes · **Format:** individual

Answers with reasoning

The scenario

By the late 1980s, prairie lupine was spreading across parts of the Pumice Plain at Mount St. Helens, and other plants and small animals seemed to gather wherever it grew. That raises a cause-and-effect question. Did lupine change the plain in ways that helped other populations? Or did lupine simply grow in spots that were already wetter or richer, where other living things would have done well anyway? To find out, a research team marked twelve permanent plots, each 4 square meters, on bare pumice in 1986, before lupine had reached that part of the plain. In 1986 the team also measured soil moisture and found it the same in all twelve plots, about 9 percent water. Over the next four years lupine seeds arrived on their own in six of the plots (Group L). The other six never got lupine (Group B, for bare). Every four years the team measured the same things in the same way.

Facts about prairie lupine — Prairie lupine is a legume, a member of the pea family. Small bumps called nodules on its roots hold bacteria that take nitrogen gas from the air and change it into a form plants can use. Nearly all plants need usable nitrogen to grow, and fresh pumice has very little. When lupine leaves and stems die, they decay into the pumice and add nitrogen and other nutrients. Living lupines form low mats that trap windblown seeds and give insects food and shelter; spiders and beetles hunt those insects. Living lupines also use water and space that a seedling right beside them could have used.

Pumice Plain plots with and without lupine, 1986 to 1998 (teaching dataset)

Simulated teaching dataset: the numbers are invented to be realistic, not measured.

Year	Group	Lupine cover (% of plot)	Usable soil nitrogen (mg/kg)	Seedlings of other plants (per plot)	Insects and spiders (per trap per week)
1986	L (lupine arrived later)	0	12	0.3	2
1986	B (no lupine)	0	11	0.5	2
1990	L	18	16	0.6	9
1990	B	0	12	0.7	3
1994	L	46	38	2.9	21
1994	B	0	13	1.0	4
1998	L	52	61	7.5	26
1998	B	0	15	1.8	5

Simulated data for teaching. Each value is the average of six plots. Usable soil nitrogen is in milligrams per kilogram of pumice. Seedlings are of species other than lupine. Insects and spiders were caught in one small cup trap per plot over one week.

Warm-up: organize the evidence

- How much did usable soil nitrogen change from 1986 to 1998 in Group L, and in Group B? How many times larger was Group L's increase? Show your work.

Answer: Group L: $61 - 12 = 49$ mg/kg increase. Group B: $15 - 11 = 4$ mg/kg increase. $49 \div 4 = 12.25$, so Group L's increase was about 12 times larger.

Why: Change is the later value minus the earlier value in the same group; the comparison of the two changes shows the effect is far larger where lupine grew.

Also acceptable: Accept 'about 12 times' or '12.25 times'. Comparing the 1998 values directly (61 versus 15, about 4 times higher) is a correct comparison but answers a different question; give partial credit.

2. Look only at the 1986 rows and the moisture measurement in the scenario. How similar were the two groups before lupine arrived, and why does the argument need this information?

Answer: In 1986 the groups were almost identical: soil nitrogen 12 and 11 mg/kg, seedlings 0.3 and 0.5 per plot, insects and spiders 2 and 2 per trap, no lupine in either, and the same soil moisture (about 9 percent). The argument needs this because it rules out the other explanation: if the Group L plots had already been wetter or richer, the later differences could have come from the plots themselves. Since they started out the same, the differences that appeared after lupine arrived are better explained by the lupine.

Why: A baseline measured before the change is the 'before' half of a before-and-after comparison and the check that the two groups were fairly matched.

Also acceptable: Accept 'it shows the plots were a fair match before the experiment started'.

- Uses at least two 1986 values or the moisture measurement to show the groups were similar
- Explains that this rules out pre-existing differences

3. In Group L, insects and spiders jumped between 1986 and 1990, but seedlings of other plants hardly changed until after 1990. Use numbers to show this, and suggest a reason for the different timing.

Answer: Insects and spiders in Group L went from 2 to 9 per trap by 1990 (4.5 times as many) while lupine cover was still only 18 percent. Seedlings went only from 0.3 to 0.6 by 1990, then to 2.9 in 1994 and 7.5 in 1998. A reason: insects use living lupine right away for food and shelter, and spiders follow the insects. Seedlings depend on usable nitrogen, which built up slowly as lupine leaves and stems died and decayed (16 in 1990, 38 in 1994, 61 in 1998), so the seedling increase lagged behind the nitrogen.

Why: Timing is evidence: the cause should come before the effect, and different effects can have different lags depending on the mechanism.

Also acceptable: Accept 'seeds had to blow in and get trapped first' as a second reason for the seedling lag.

- Uses 1986 and 1990 numbers for insects and for seedlings
- Gives a reason linked to living lupine (insects) versus nitrogen build-up from dead lupine (seedlings)

Your argument

Answer: Claim: The arrival of lupine raised the amount of usable nitrogen in the pumice, and as a result seedlings of other plants and the insects and spiders on the plain increased. Evidence: (1) In 1986, before lupine arrived, the two groups were alike: nitrogen 12 and 11 mg/kg, seedlings 0.3 and 0.5 per plot, insects and spiders 2 per trap in both. (2) By 1998, Group L had 61 mg/kg of usable nitrogen while Group B had only 15; Group L's nitrogen rose by 49 mg/kg and Group B's by only 4. (3) Seedlings of other plants rose from 0.3 to 7.5 per plot in Group L but only from 0.5 to 1.8 in Group B, so in 1998 Group L had about 4 times as many. (4) Insects and spiders rose from 2 to 26 per trap in Group L but only from 2 to 5 in Group B. (5) Timing: insects rose first (9 per trap by 1990), nitrogen climbed steadily (16, 38, 61), and seedlings rose mainly after nitrogen had built up (2.9 in 1994, 7.5 in 1998). Reasoning: Lupine roots hold bacteria that turn nitrogen gas into usable nitrogen, and dead lupine parts add it to the pumice, so lupine changed a physical component, the soil. Nitrogen is a resource nearly all plants need and fresh pumice lacks, so more usable nitrogen let more seedlings survive, and living lupines also trapped seeds. Insects use living lupine for food and shelter, and spiders and beetles eat the insects, which explains why they rose first. The other explanation, that lupine just landed in better spots, does not fit: in 1986 the plots matched on nitrogen, seedlings, insects and moisture, and the six Group B plots, measured the same way in the same years, changed only a little. The pattern repeated across six plots in each group, not just one. One limit: lupine picked its own plots, so the groups could still differ in something nobody measured, and the study covers one part of the plain.

Why: This is the solved model response. Full credit requires a claim that names the soil change and at least two population changes; three or more pieces of evidence with years and numbers, including a same-year comparison and the 1986 baseline; reasoning that explains the nitrogen mechanism, rules out the 'better spots' explanation with the baseline and Group B, and names a limit.

Also acceptable: A claim that names only one population can earn 3 on the claim row if evidence for the others is still cited. A student who claims lupine helped 'all life' on the plain has overreached; Group B and q4 show the effect is local and mixed.

- Claim names a physical change (usable soil nitrogen) and at least two populations that increased
- At least three evidence items with years and values
- Evidence includes a same-year L versus B comparison and the 1986 baseline
- Reasoning explains the nitrogen-fixing mechanism and why nitrogen matters to plants
- Reasoning uses the baseline and Group B to rule out the alternative explanation
- Names one limit (non-random colonization, one area, averages, sampling frequency)

After you write

4. Ecologists studying real lupines on the Pumice Plain found that seedlings of other plants often struggled right next to a living lupine, but did especially well in spots where a lupine had grown and then died. Does this finding weaken your claim, strengthen it, or change part of it? Explain.

Answer: It changes part of the claim rather than overturning it. Lupine still changes the soil and still affects other populations, but the effect on seedlings runs in two directions: a living lupine competes with seedlings beside it for water and space, while a dead lupine leaves nitrogen-rich ground where seedlings do well. So the claim should say that lupine helps other plants mainly through the nitrogen it leaves behind as it dies back, not simply by being present. This fits the table, where seedlings rose most in the later years, after many lupine parts had died and nitrogen had built up.

Why: This reflects published Pumice Plain research (del Moral and Wood, 1993) and models how new evidence refines an argument's mechanism.

Also acceptable: Accept 'strengthens the claim' if the student argues that the finding confirms the nitrogen mechanism, as long as competition by living lupines is also acknowledged.

- States whether the claim is weakened, strengthened or refined, with a reason
- Explains competition by living lupines and enrichment by dead ones
- Connects the finding to the timing in the table

5. Seedlings in Group B also rose a little, from 0.5 to 1.8 per plot. Give one possible reason, and explain with numbers why this does not undo your claim.

Answer: Possible reasons: seeds blew in from nearby lupine plots or from the edges of the plain; a few hardy plants can slowly establish on pumice even without lupine; weathering of the pumice released a little nitrogen (Group B rose from 11 to 15). It does not undo the claim because Group L rose far more: seedlings rose by $7.5 - 0.3 = 7.2$ per plot in Group L but only $1.8 - 0.5 = 1.3$ in Group B, and Group L ended with about 4 times as many (7.5 versus 1.8).

Why: A comparison group is expected to change somewhat on its own; the argument rests on the difference between the groups, not on Group B staying perfectly still.

Also acceptable: Accept the ratio comparison (Group L about 25 times its 1986 value, Group B about 3.6 times).

- Gives a plausible reason for the small Group B rise
- Compares the size of the two changes with numbers

Scoring rubric

Criterion	4 • Exemplary	3 • Proficient	2 • Developing	1 • Beginning
Claim	Names lupine's change to a physical component (usable soil nitrogen) and at least two populations that changed, with directions, in one clear statement.	Names the soil change and one population, or names two populations without the soil change.	States that lupine 'helped' or 'changed things' without naming what changed.	No claim, or a claim the data contradict.

Evidence: before-and-after and with-and-without	Three or more accurate pieces of evidence with years and values, including the 1986 baseline (before-and-after) and a same-year Group L versus Group B comparison (with-and-without).	Three accurate pieces with numbers, but either the baseline or the same-year comparison is missing.	One or two pieces, or evidence described without numbers.	Evidence missing, invented or misread from the table.
Reasoning: mechanism and the other explanation	Explains how lupine's root bacteria and decaying parts add usable nitrogen and why nitrogen limits plants, links insects to living lupine, and uses the baseline and Group B to rule out the 'better spots' explanation.	Explains the mechanism clearly but treats the alternative explanation briefly or only through Group B.	Restates the evidence, or gives a mechanism with an error (for example, that lupine makes nitrogen out of nothing).	No reasoning, or reasoning unrelated to the evidence.
Repetition, limits and scientific language	Notes that the pattern held across six plots per group, names a real limit (lupine chose its own plots, one area, averages), and uses population, resource and nitrogen fixation correctly.	Names a limit and uses terms correctly, but does not mention repetition across plots.	Limit vague ('it could be wrong') or terms used loosely.	No limit and frequent misuse of terms.

Teacher notes

The dataset is simulated, but it follows published Pumice Plain research: prairie lupine (*Lupinus lepidus*) fixes nitrogen through root-nodule bacteria and enriches the pumice locally, its patches trap seeds and host insects, and other plants established best where lupines had grown and died while living lupines also competed with nearby seedlings (del Moral and Wood, 1993). Because lupine colonized the plots on its own, this is an observational comparison, not an experiment; the best arguments name that as the main limit, and the extension asks students to design the experiment. The rubric criteria match the four features of a strong argument on slide 22 (before-and-after, with-and-without, mechanism, repetition). Common errors: comparing 1998 values instead of changes in q1, claiming lupine 'makes' nitrogen rather than converting nitrogen gas from the air, and claiming that lupine helped every population. Students who missed exit-ticket question 3 should revisit their W7 corrections before this sheet.

Scaffold offered to students: Sentence frames for each part

Claim: 'When lupine arrived, it changed the ___ of the pumice, and as a result ___ and ___ increased.'

Evidence: 'In 1986, Group L had ___ and Group B had ___. By 1998, Group L had ___ while Group B had ___.'

Reasoning: 'This shows ___ because lupine ___. Since the two groups were alike in 1986, the difference cannot be explained by ___. One limit is ___.' Circle the numbers in the table before you write so you can find them again quickly.

Extension: Design the experiment that would settle it

In this study, lupine chose the plots by arriving on its own, so the team could not be completely sure the six lupine plots were not special in some way they did not measure. Design an experiment that removes that doubt. Describe how you would decide which plots get lupine (for example, by planting seeds in plots chosen by coin flip), what you would do in comparison plots, and whether you would add a third group of plots where planted lupines are removed after a few years. Predict the results for each group, and explain how they would separate the effect of living lupines from the effect of dead ones.