

What Is a Bee Visit Worth? Orchard Data and Replacement Cost

Learning target: I can graph and analyze orchard data to find how pollination affects a harvest, and use replacement-cost reasoning to estimate what a pollination service is worth and what that number leaves out.

Data and graphing

About 50 min

Individual

MS-LS2-5 · practice

MS-LS2-1 · supports

data analysis

independent practice

Standards connections

MS-LS2-5 (practice): Students put numbers on one ecosystem service and compare renting it with replacing it by human labor, the kind of economic evidence used when evaluating competing solutions for maintaining a service. The data are simulated, so this builds the practice rather than assessing the PE.

MS-LS2-1 (supports): The harvest levels off when another resource, not pollination, becomes limiting; students meet the idea of a limiting factor from data, which this PE develops for populations.

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

Answers with reasoning

Part A: More bees, more almonds?

A grower divided her orchard into eight test blocks of the same almond varieties, soil and watering. During bloom she placed a different number of rented honey bee colonies per acre in each block, keeping the blocks far enough apart that bees mostly stayed in their own block. The block with no colonies still received a few visits from wild bees that nest nearby. At harvest she recorded how many flowers had become nuts and how many pounds of almond kernels each acre produced.

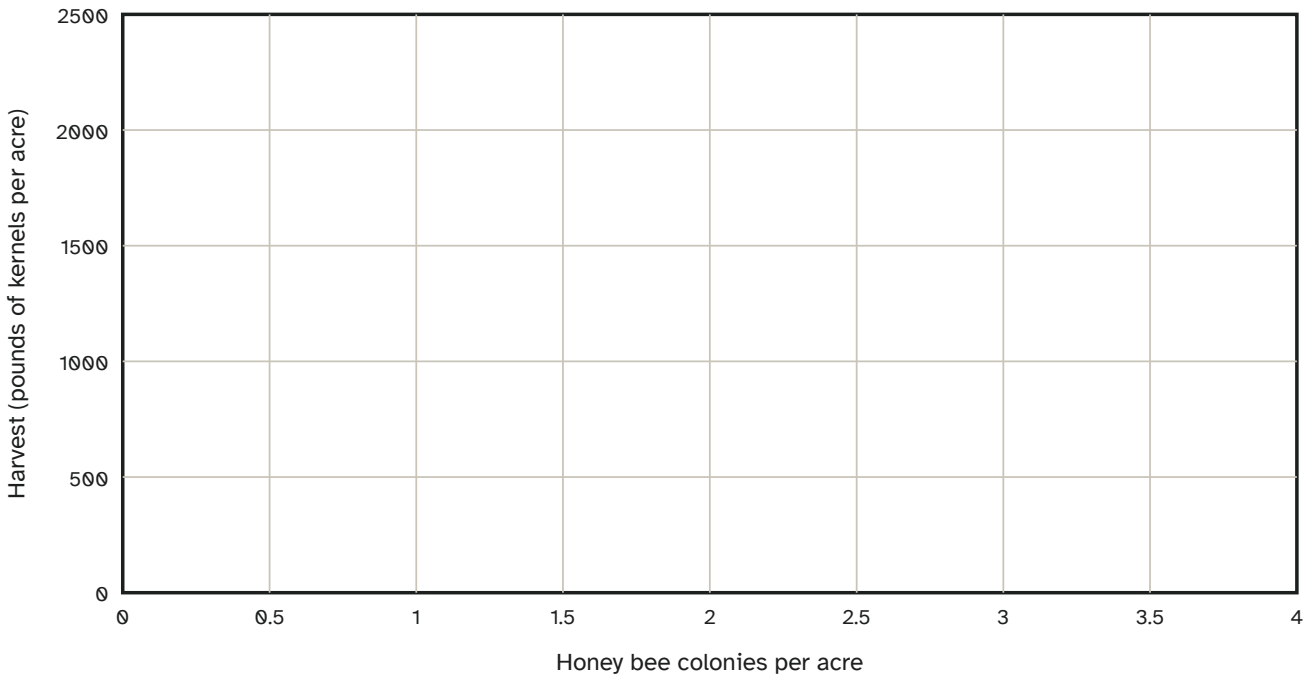
Honey bee colonies per acre and almond harvest in eight test blocks (teaching dataset)

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

Colonies per acre	Flowers that became nuts (%)	Harvest (pounds of kernels per acre)
0	4	350
0.5	14	1050
1.0	21	1550
1.5	26	1900
2.0	29	2100
2.5	30	2180
3.0	30	2200
4.0	31	2220

Simulated data for teaching. The shape of the pattern, rising fast and then leveling off, is realistic; the values are invented.

Almond harvest and honey bee colonies per acre



1. How many more pounds per acre did the block with 2.0 colonies produce than the block with none? By what percent did the harvest increase? Show the calculation.

Answer: $2,100 \text{ lb} - 350 \text{ lb} = 1,750 \text{ lb}$ more per acre. Percent increase = $1,750 \div 350 \times 100 = 500\%$. The 2.0-colony block produced 6 times as much as the block with no colonies.

Why: Percent increase is the change divided by the starting value. Students often divide by the larger number ($1,750 \div 2,100 = 83\%$), which is the wrong base.

Also acceptable: Accept '6 times as much' alongside 500%.

2. Describe the shape of your graph. Between which two neighboring blocks did one extra half colony per acre add the most harvest? After which point did extra colonies add almost nothing? Suggest one reason the harvest stops rising even though more bees are added.

Answer: The harvest rises steeply at first and then levels off. The biggest gain from one half colony was from 0 to 0.5 colonies per acre (350 to 1,050 lb, +700 lb). After about 2.5 colonies per acre, extra colonies added almost nothing (+20 lb from 2.5 to 3.0 and +20 lb from 3.0 to 4.0). Once nearly every flower is pollinated, something else limits the harvest: how many nuts the tree can fill with the water, nutrients and sugar it has, or the number of flowers on the trees.

Why: This is a diminishing-returns curve. The leveling off shows that pollination is no longer the limiting factor.

Also acceptable: Accept 'after 2.0' for the leveling point if the student cites the small gains that follow.

- Describes rising then leveling off
- Identifies 0 to 0.5 as the largest gain
- Identifies about 2.5 colonies as the point after which gains are tiny
- Gives a plausible limiting factor other than bees

3. In this scenario the grower earns \$2.50 per pound of kernels and pays \$200 to rent one colony for the bloom. Complete the table. Extra income = extra harvest $\times$ \$2.50. Extra rent = extra colonies $\times$ \$200. Net = extra income – extra rent.

Answer: 1.5 to 2.0: extra harvest $2,100 - 1,900 = 200 \text{ lb}$; income $200 \times \$2.50 = \$500$; rent $0.5 \times \$200 = \$100$; net $+\$400$. 2.0 to 3.0: extra $2,200 - 2,100 = 100 \text{ lb}$; income $\$250$; rent $1 \times \$200 = \$200$; net $+\$50$. 3.0 to 4.0: extra $2,220 - 2,200 = 20 \text{ lb}$; income $\$50$; rent $\$200$; net $-\$150$.

Why: Each step compares the extra income with the extra rent. The net shrinks and becomes negative as colonies are added.

Also acceptable: Allow follow-through credit if an earlier harvest difference was misread but later arithmetic is correct.

- Extra harvest values 200, 100 and 20 lb
- Income \$500, \$250, \$50
- Rent \$100, \$200, \$200
- Net +\$400, +\$50, -\$150

4. Using your table, how many colonies per acre would you recommend for this orchard? Give a reason based on the numbers and one reason a grower might choose a little more than that.

Answer: About 2 colonies per acre. Going from 1.5 to 2.0 earns \$400 more per acre, but going from 2.0 to 3.0 earns only \$50 more, and above 3.0 the grower loses money. A grower might rent a little more (2.5 or 3) as insurance against cold, rainy or windy bloom weather, when bees fly less and each colony does less pollinating.

Why: The decision uses the net gain per step and recognizes that real conditions vary from year to year.

Also acceptable: Accept 3.0 if the student notes the net is still slightly positive and explains the weather risk.

- Recommends about 2 (accept 2 to 3) colonies per acre
- Uses the net values from q3
- Gives one sensible reason for a little extra

Part B: What if there were no bees to rent?

Imagine honey bees could not be rented at all. A crew could still pollinate almond flowers by hand, dabbing pollen from the second variety onto each flower with a small brush or puffer. The cost of doing a natural job with human labor or machines is called its **replacement cost**. Use the teaching numbers below.

Teaching numbers for hand pollination (teaching dataset)

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

Quantity	Value
Almond trees per acre	110
Trees one trained worker can hand-pollinate in an 8-hour day	4
Labor cost per worker per hour	\$25
Pollen collected and prepared for hand use, per acre	\$150
Working days during bloom	15
Honey bee rental: colonies per acre and price per colony	2 colonies at \$200 each
Price the grower receives for kernels	\$2.50 per pound

Simulated values for teaching. Real hand-pollination rates depend on tree size and flower number and would vary widely.

5. Calculate the cost of hand-pollinating one acre. First find the worker-days per acre, then the worker-hours, then the labor cost, then add the pollen.

Answer: Worker-days per acre = $110 \text{ trees} \div 4 \text{ trees per day} = 27.5 \text{ worker-days}$. Worker-hours = $27.5 \times 8 = 220 \text{ hours}$. Labor = $220 \times \$25 = \$5,500$. Total = $\$5,500 + \$150 = \$5,650$ per acre.

Why: Unit tracking: trees $\div$ (trees per day) gives days; days $\times$ hours per day gives hours; hours $\times$ dollars per hour gives dollars.

Also acceptable: None.

6. How many times more does hand pollination cost per acre than renting 2 colonies per acre? Round to one decimal place.

Answer: Bee rental = $2 \times \$200 = \$400$ per acre. $\$5,650 \div \$400 = 14.1$. Hand pollination costs about 14 times as much.

Why: Ratio of the two costs per acre.

Also acceptable: Accept 14 times.

7. Bloom lasts 15 working days. How many hand-pollination workers would a 100-acre orchard need every day of bloom to finish in time? Round up to a whole worker and explain why you round up.

Answer: Total worker-days = $27.5 \times 100 = 2,750$ worker-days. Workers needed = $2,750 \div 15 = 183.3$, so 184 workers every day of bloom. Round up because 183 workers would not finish in time; you cannot hire a third of a worker.

Why: This shows the practical problem with replacement: the job must be done in a short window.

Also acceptable: Accept 183.3 with the statement that 184 are needed.

8. At 2.0 colonies per acre the orchard produced 2,100 pounds per acre. Calculate the income from one acre and compare it with your answer to q5. What does the comparison tell you about the value of the pollination service?

Answer: Income = $2,100 \times \$2.50 = \$5,250$ per acre. Hand pollination would cost \$5,650, which is \$400 more than the whole crop is worth, before paying for water, fertilizer, harvesting or land. The pollination service is worth so much that without it this orchard could not make money at all.

Why: When replacing a service costs more than the product, the service is essential to the business.

Also acceptable: Accept 'the farm would lose at least \$400 per acre'.

- Correct income \$5,250
- States that hand pollination costs more than the income
- Concludes the service is essential or very valuable

9. A grower says, 'Bees are worth exactly \$400 an acre to me, because that is what I pay.' Explain why the rent is not the full value of the pollination service. Then give two things that a replacement-cost number also leaves out.

Answer: The rent pays the beekeeper for managing, moving and caring for colonies. It does not pay for the flowers, wild land and farms in other states that fed the bees all year, or for wild bees that also visit for free, so the service rests on ecosystems the grower never pays for. The rent is also set by supply and demand; if colonies became scarce, the price could jump. A replacement-cost number also leaves out: (1) whether the replacement would work as well (hand pollination might miss flowers or damage them); (2) what happens if no replacement is possible at any price, such as when there are not enough workers; (3) benefits beyond the orchard, such as bees pollinating wild plants and other crops, and the cultural value of healthy bee populations; (4) costs it hides, such as worker injuries or the energy used by machines.

Why: The point is that prices and replacement costs are useful but incomplete measures of what ecosystems are worth.

Also acceptable: Accept any two well-reasoned omissions.

- Explains that rent pays for management, not the whole service
- Mentions the ecosystems that support bees or wild bees
- Two distinct things a replacement cost leaves out

Teacher notes

Both datasets are simulated. The harvest curve is shaped like real pollination studies (steep rise, then a plateau) and the values are in a realistic range for California almonds, about 2,000 to 2,500 pounds of kernels per acre in good years; two colonies per acre is the common industry guideline for varieties that need cross-pollination. Rental price and kernel price change every year, so treat \$200 per colony and \$2.50 per pound as round teaching values. Hand pollination of fruit trees is real in some places, but the labor numbers here are invented; do not present them as a real cost estimate. The extension answer: rent savings = $0.5 \text{ colony} \times \$200 \times 100 \text{ acres} = \$10,000$ per year; minus \$2,000 upkeep leaves \$8,000 per year; $\$25,000 \div \$8,000 = 3.1$, so the strips pay for themselves during the fourth year.

Scaffold offered to students: Calculation path for Part B

Worker-days per acre = trees per acre $\div$ trees per worker per day. Worker-hours = worker-days $\times$ 8. Labor cost = worker-hours $\times$ \$25. Add \$150 for pollen. For q7, total worker-days for the orchard = worker-days per acre $\times$ 100, then divide by the number of days in bloom. Check that every number you write has a unit (trees, days, hours, dollars).

Extension: Wild bees in the budget

Suppose planting strips of native wildflowers along the orchard edges costs \$25,000 to establish and \$2,000 a year to maintain, and lets the grower rent 1.5 colonies per acre instead of 2.0 with the same harvest, because native bees nesting in the strip do some of the pollinating. For a 100-acre orchard, how many years would it take for the rent savings to pay for the strips? Then describe one benefit of the strips that does not show up in your calculation and one risk the grower takes by relying on wild bees.