

The Lake Can Give Ten: A Token Model of People, Fish and Fixes

Investigation question: A lake can regrow only so many fish each year. What happens when more and more consumers fish it, when each family starts using more fish, and when a village tries different fixes? And why does a wild fish-eater's population crash while the village's keeps rising?

Collaborative systems modeling

Groups of 4

2 sessions

Setup 5 · Activity 90 · Cleanup 5 min

MS-LS2-5 · practice

MS-ETS1-2 · practice

MS-ESS3-4 · supports

Name _____

Group _____

Date _____

Your role today

- ☐ **Lake keeper (one in each pair):** Moves the beans: takes out the catch, keeps the last 4 fish on the Reeds card, adds regrowth from the supply bowl, and never lets the lake hold more than 60.
- ☐ **Bookkeeper (one in each pair):** Works out each year's fish needed, imports and newcomers from the rule card and fills in the pair's table.
- ☐ **Rule checker (one bookkeeper, switching each part):** Reads each step aloud before the lake keeper acts and checks every row: fish at end = fish at start – caught + regrowth, never more than 60.
- ☐ **Reporter (one lake keeper):** Posts the group's results on the class charts and reads them aloud during the debrief.

Safety

- Dried beans are a choking hazard and are not food: never put them in mouths, noses or ears. Raw dried kidney beans contain a natural toxin that only long boiling destroys, so no bean from the kit is ever eaten.
- Spilled beans are a slip hazard on hard floors; keep the cups over the desk and pick up spills right away.
- Wash hands after handling the beans. Use paper counters for any student with a legume allergy.
- No heat, flames, chemicals or sharp tools are used.

Procedure

1. Session 1. Read the rule card and the regrowth table together. Before moving any beans, answer q1: predict how the otter run and the village run will differ.
2. Part A setup. Split into two pairs. Each pair puts 40 beans in its lake cup, sets 4 of them on its Reeds card (they are still in the lake but can never be caught) and writes 4 consumers for year 1. Pair 1 runs the otter rule; pair 2 runs the village rule. Both use the same growth rule.

3. Run one year with the four steps on the rule card: fish (take out 1 fish per consumer, never the 4 on the reeds); shortfall (otters that got no fish leave or die; the village records the missing fish as imports); regrow (count the fish left, look up the regrowth, add it from the supply, never above 60); grow (add newcomers only if every consumer ate). The rule checker reads each step aloud first.
4. The bookkeeper fills the row, and the rule checker confirms that fish at end = fish at start – caught + regrowth before the next year starts. Year 1 is already filled in on the sheet; both pairs should match it.
5. Run 12 years, swapping lake keeper and bookkeeper after year 6. Then copy the other pair's consumers, lake counts and imports into the comparison table and graph both runs on one set of axes: consumers in one color, lake fish in the other, a solid line for the otter run and a dashed line for the village run.
6. Part B. Reset each lake to 40 fish and 4 families. Both pairs now use the village rule with slow growth: add exactly 1 family each year. Pair 1 runs B1: every family needs 1 fish every year. Pair 2 runs B2: each family needs 1 fish in years 1 to 4 and 2 fish from year 5 on. Run 12 years and fill in the Part B table.
7. Post the Part A village, B1 and B2 results on the class chart: the first year fish needed was more than the regrowth, the first year the lake ended below 20, fish imported in 12 years, and families and fish needed in year 12. Copy the class chart onto your sheet. Count the beans back into the bag.
8. Session 2, Part C. Read the solution cards and the three criteria. Each pair chooses a design: one card, or a package of two cards costing 8 coins or less in total. Answer q2 before running.
9. Reset the lake to 40 fish and 4 families and run the fast-growing village (the Part A village rule) for 12 years with your design's rule changes. Fill in the Part C table, tracking lake plus reserve at the end of every year and where every fish came from: the lake, the farm or imports.
10. Fill in the totals row, check your design against the criteria and post it on the Part C class chart. If it failed, change one card and run again. Copy the class chart, count the beans back into the bag, and answer the analysis questions on your own.

Record your observations

Lab 1 recording sheet: The Lake Can Give Ten

Each bean stands for a fish (think of it as a school of fish). Each round is one year. A **consumer** is one otter or one village family; each needs 1 fish a year unless a rule says otherwise. The lake regrows fish every year, but how many depends on how many are left. Fish are hard to grow back when few are left, and a crowded lake has little room for more.

Rule card: the four steps of every year

Step	Otter rule	Village rule
1. Fish	Take 1 fish per otter. The 4 fish on the reeds can never be caught.	Take 1 fish per family. The 4 fish on the reeds can never be caught.
2. Shortfall	Each otter that got no fish leaves or dies.	Missing fish are bought from far away. Record them as imported.
3. Regrow	Count the fish left. Add new fish from the regrowth table. Never more than 60.	Same as the otter rule.
4. Grow	Only if every otter ate: add 1 newcomer for every 4 otters (round down), at least 1.	Every family ate (lake or imports): add 1 newcomer for every 4 families (round down), at least 1.

Regrowth table

Fish left in the lake after fishing	New fish added
1 to 9	2
10 to 19	5
20 to 29	8
30 to 39	10
40 to 49	8
50 to 59	4
60	0

- Prediction before Part A: the otter run and the village run start the same and use the same growth rule. How do you think the two runs will differ by year 12, and why?

Part A: your pair's run (circle one: otter rule / village rule)

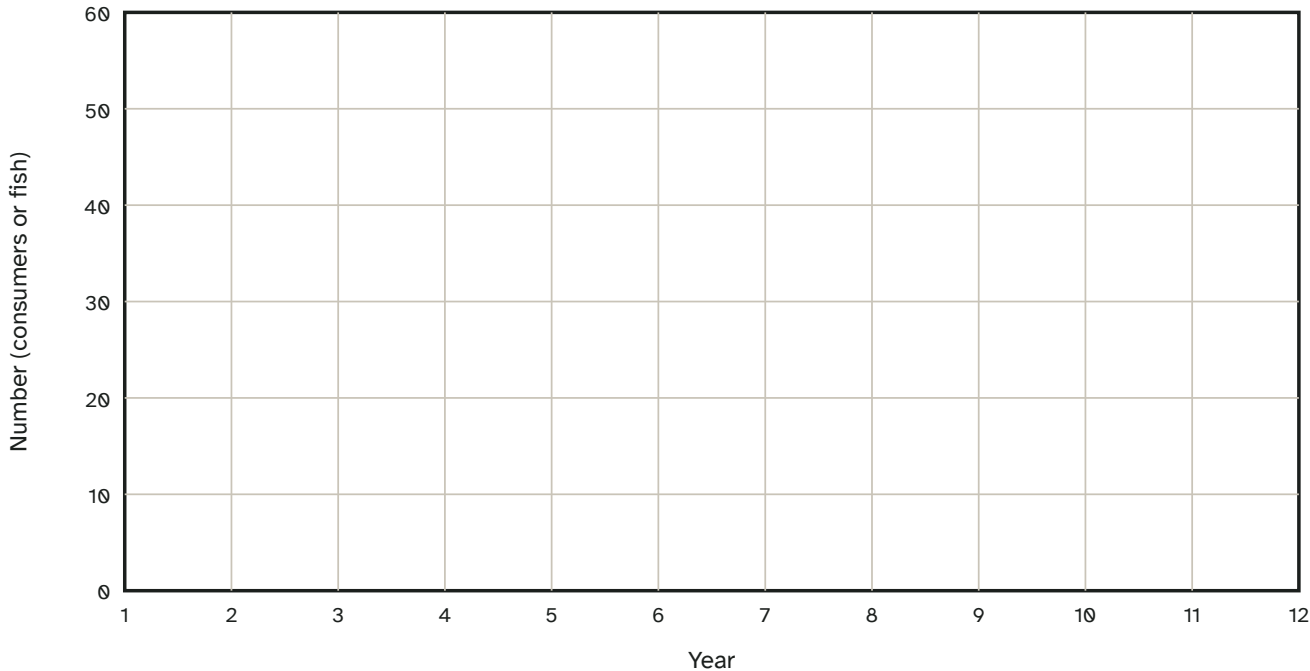
Year	Consumers at start	Fish needed	Caught from lake	Hungry otters or imported fish	Fish left after fishing	Regrowth added	Fish at end of year	Consumers next year
1	4	4	4	0	36	10	46	5
2								
3								

Year	Consumers at start	Fish needed	Caught from lake	Hungry otters or imported fish	Fish left after fishing	Regrowth added	Fish at end of year	Consumers next year
4								
5								
6								
7								
8								
9								
10								
11								
12								

Part A: both runs side by side

Year	Otters at start	Lake at end (otter run)	Families at start	Lake at end (village run)	Fish imported by the village
1	4	46	4	46	0
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					

Part A: consumers and lake fish, otter rule and village rule



Part B: your pair's run (circle one: B1 / B2)

Year	Families	Fish per family	Fish needed	Caught from lake	Imported	Fish at end of year
1	4	1	4	4	0	46
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						

Class chart, Part B: when did each lake tip?

Run	First year fish needed was more than regrowth	First year the lake ended below 20	Fish imported in 12 years	Families in year 12	Fish needed in year 12
Part A village (fast growth, 1 fish per family)					
B1 (1 new family a year, 1 fish per family)					
B2 (1 new family a year, 2 fish per family from year 5)					

Part C solution cards (budget: 8 coins)

Card	Cost (coins)	Rule change
Q: Catch limit	2	The village may take at most 10 fish a year from the lake. Any other fish it needs are imported.
M: Larger-mesh nets	3	Young and small fish slip through and grow up: add 2 to the regrowth every year. Big-mesh nets catch at most 12 fish a year. (With card Q, the limit is 10.)
R: No-fishing reserve	4	Before year 1, move 10 of the 40 fish into the reserve cup; they are never caught. After regrowth each year, add 2 fish from the supply to the lake (young fish swimming out). The reserve stays at 10.
F: Fish farm pond	5	Before anyone fishes, the farm supplies up to 6 fish to the village each year. Farm waste enriches the water: subtract 1 from the regrowth every year.
E: Ice house	3	With ice and drying racks, less fish spoils: fish needed = families minus 1 for every 4 families (round down).

Part C criteria (fast-growing village, 12 years) – 1. Lake health: the lake plus the reserve holds at least 20 fish at the end of every year. **2. Local supply:** at least 75 percent of the fish the village uses in 12 years come from the lake or the farm, not imports. Percent local = (fish from lake + fish from farm) ÷ total fish needed × 100. **3. Budget:** the cards cost 8 coins or less in total.

2. Part C prediction: name your design (cards and total cost). Predict which criterion it is most likely to fail, if any, and explain why using the card rules.

Part C: your design's run (fast-growing village)

[illegible]

Class chart, Part C: which designs met all three criteria?

[illegible]

Analysis questions

3. Part A: in which year did the lake first end the year with fewer fish than it started with? Compare the fish caught that year with the fish that regrew.

4. From year 6 to year 10 the lake lost more fish each year: 2, 2, 5, 10, then 17. Use the regrowth table to explain why the decline sped up, even though the lake had held steady for years.

5. Compare the otters and the village in years 11 and 12. What happened to each population, and which single rule made the difference?

6. The village never went hungry. In the real world, where would imported fish come from? Does importing remove the impact on ecosystems or move it? Explain.

- 7.** Part B: use the class chart to compare B1, B2 and the Part A village in year 12 (families, fish needed, fish imported, first year below 20). Which pushed the lake down sooner, faster growth in families or more fish per family? Use numbers.

- 8.** Total use = families $\times$ fish per family. Calculate year 12's total for the Part A village (33 families, 1 fish each) and for B2 (15 families, 2 fish each). How many families using 1 fish each would match B2's total? Show your work.

- 9.** Part C: which single cards met all three criteria? Which designs did? Give the numbers for one design that passed and one single card that failed.

- 10.** Which design would you recommend to the village? Name the criterion it meets with the most room to spare, the one it meets most narrowly, and one tradeoff the village accepts with it.

- 11.** The growth rule takes the village from 33 families in year 12 to 188 families in year 20. Predict whether the designs that passed at 12 years would still pass at 20 years, and explain what this suggests about engineering fixes when demand keeps growing.

- 12.** Name two ways this model is simpler than a real lake and its fishery, and say how each might change the results.
