

Fixing Lake Vesipuro: Test a Restoration Plan on Paper

Investigation question: Which combination of cutting nutrient inflow, netting out plankton-eating fish and stocking predatory fish will bring a fictional murky lake back to clear water within four years, within budget, and keep it clear afterward?

Data-driven decision

Groups of 4

2 sessions

Setup 5 · Activity 85 · Cleanup 5 min

MS-ETS1-4 · practice

MS-LS2-4 · practice

MS-LS2-3 · supports

Scientific purpose

Students read three years of simulated monitoring data from a fictional lake, state the food-web bet behind each possible fix, and then use a simple rule-based model to generate year-by-year predictions for two plans. They compare the output with the criteria and the budget, modify a plan, run it again, and commit to a decision with a written justification. The lab makes the engineering spread's test-measure-modify cycle something students do themselves, and it ties nutrient inflow (matter) to algae and predators (food-web effects) in one system.

Why this helps students with this chapter

The textbook tells the lake story as a finished success in two steps. Running the numbers themselves shows students that a plan can help without succeeding, that stopping an action can undo it, that a cheap plan and an expensive plan can both meet the criteria for different reasons, and that a simple model gives directions and rough sizes, not certainty. Having to spend a budget forces a real decision instead of 'do everything'.

Standards connections

MS-ETS1-4 (practice, using a model to generate data for iterative testing and modification of a proposed process): Students run a supplied rule-based lake model to produce four years of predicted data for each plan, compare the results with criteria and constraints, modify the plan and run it again. The model is given rather than developed by students, so the lab practices the PE rather than fully assessing it.

MS-LS2-4 (practice, arguing from evidence that a change to a biological component affects populations): The decision must be justified with model output and the baseline data, tracing how removing or adding fish populations changes zooplankton, algae and clarity; the evidence is simulated, so this is practice toward the PE.

MS-LS2-3 (supports, nutrient inflow as matter entering the system and driving producer growth): The nutrient rule in the model makes visible that the matter arriving in sewage and runoff becomes algae; this reinforces the matter-cycling model from Lab 1 without being the main target of the lab.

Roles (rotate each session)

- **Modeler:** Applies the five model rules in order for each year and reads the results aloud.

- **Checker:** Recomputes every row independently before it is accepted, and flags any step where the rules were applied out of order.
- **Accountant:** Tracks the cost of each plan year by year, checks every criterion and constraint, and fills the criteria table.
- **Spokesperson:** Drafts the group's justification from the recorded numbers and presents the decision to the class.

Materials

Item	Quantity	Per	Note
Recording sheet with the baseline dataset, the model rule card, the plan menu and three run sheets	1	student	
Calculator	1	group	
Pencils and an eraser (runs get revised)	1 set	student	
Colored pencils for the clarity graph (one color per plan)	3	group	
Scrap paper for trial calculations	a few sheets	group	

Estimated cost: 2 to 4 per class (an estimate; Printing only; calculators and colored pencils are classroom stock.)

Safety

- Paper and pencil only; no physical hazards. Keep the discussion about the fictional lake, not about any named local water body, unless you have checked the facts.

Teacher preparation and setup

1. Run the model yourself for the five plans in the answer key so you can spot arithmetic slips quickly; the most common error is applying the predator rule in the stocking year instead of the year after.
2. Print the recording sheet; the rule card is on it, but a large copy on the board helps every group apply the rules in the same order.
3. Decide whether to tell students before they start that the fictional lake is based on the textbook's Finnish lake story, or to let them discover the resemblance in the debrief.
4. Post the criteria and constraints where every group can see them: clarity at least 2.0 m in year 4, still at least 2.0 m in year 5 with no new spending, predatory fish for anglers by year 4, and a total cost of at most 9 units over years 1 to 4.

Investigation design

Independent variable The restoration plan: which actions (divert nutrient inflow, net out roach, stock predatory fish) are taken and in which years.

Dependent variable	The model's predicted nutrient score, roach index, zooplankton index, algae index and clarity depth for each year, and the plan's total cost.
Controlled	The same rule card for every plan; The same starting conditions (N = 8, R = 10); Rules applied in the same order every year; The same criteria, constraints and budget for every group
Trials	Each group runs at least three plans (two original, one modified); the class compares decisions across groups.
Comparison	Plans are compared on year-4 clarity, year-5 clarity with no spending, presence of predatory fish, and total cost.

Student procedure

1. Session 1. Read the baseline dataset and answer q1 and q2: describe the lake's problem with numbers, and write the sign chain the food-web model is betting on (fewer roach → more zooplankton → fewer algae → clearer water).
2. Read the rule card together. Practice the rules on the 'no action' plan for one year: N stays 8, R stays 10, Z = 0, A = 8, clarity = 0.8 m. Every group should get these numbers before going on.
3. Choose two plans from the plan menu that fit the budget (at most 9 units over years 1 to 4). Write each plan's actions in the first column of run sheets A and B.
4. Run plan A for years 1 to 5, one year at a time, applying the rules in order: nutrients, roach, zooplankton, algae, clarity, then cost. The checker recomputes each row before the group moves on. Year 5 has no spending; it tests whether the result holds.
5. Run plan B the same way. Plot clarity against year for both plans on the graph in two colors, and draw the 2.0 m criterion line across the graph.
6. Fill the criteria table for plans A and B. Answer q3: which criteria did each plan meet or miss, and by how much?
7. Session 2. Modify one plan to fix its biggest miss. You may add, remove or move an action, as long as the total stays within budget. Write the modified plan C and your reason for the change (q4). Run plan C for years 1 to 5 and plot it in the third color.
8. Decide. Compare all three plans against every criterion and constraint. Choose one, and write the justification (q5): the numbers that show it meets the criteria, why you preferred it over the other plans, and one limitation of the model that could make the real lake behave differently.
9. Present your decision in under two minutes. Listen for groups that chose a different plan and record what they valued more (cost, speed, holding, anglers). Answer the analysis questions individually.

Expected observations

- No action: N 8, R 10, Z 0, A 8, clarity 0.8 m every year.
- Net in year 1 plus stock in year 1 (cost 5): clarity 2.2, 2.4, 2.6, 2.6 m in years 1 to 4 and 2.6 m in year 5; meets C1, C2, C3 and K1.
- Divert plus stock in year 1 (cost 9): clarity 1.2, 2.2, 2.8, 3.4 m, and 3.6 m in year 5; meets everything with the clearest water, using the whole budget.

- Divert only (cost 6): clarity 1.2, 1.6, 2.0, 2.4 m, then 2.4 m; meets C1 and C2 but fails C3. Stock only (cost 3): 0.8, 1.4, 1.6, 1.8 m, then 2.0 m; fails C1. Net every year (cost 8): 2.2 m for four years, then 1.8 m; fails C2 and C3.
- Groups that try all three actions in year 1 find the cost is 11 and must drop something, which is the intended budget squeeze.

Likely difficulties

- Applying the predator rule in the stocking year. The rule says 'starting the year after'; the checker role exists to catch this.
- Forgetting the cap of 10 on R after regrowth, which makes $R = 12$ and Z negative. Z can never be below 0.
- Decimals in A and clarity (4.5, 2.6). Allow one decimal place throughout; do not round A before computing clarity.
- Treating year 5 as another spending year. It is the 'does it hold' test and has no actions.
- Groups who want to 'do everything' and exceed the budget. The constraint is the point; make them choose.

Structured debrief

1. Collect every group's chosen plan on the board with its cost and year-4 clarity. Usually two camps appear: the cheap food-web plan (net plus stock, 5 units, 2.6 m) and the expensive combined plan (divert plus stock, 9 units, 3.4 m). Ask each camp what it valued, and point out that both are defensible when the criteria are met; engineering choices between working solutions are about trade-offs.
2. Ask who ran 'divert only'. It reaches 2.0 m in year 3 and meets both clarity criteria, but it fails the anglers criterion and does nothing about the roach. Then reveal the real history: in the Finnish lake the textbook describes, diverting the sewage in the mid-1970s did much of the work, and the fish steps came later and overlapped. The textbook's clean two-step story is the model's prediction, and the scientists themselves say the exact mechanism is still debated.
3. Walk through the 'net every year' relapse. The roach rule stands for a real fact: small plankton-eating fish breed fast, so removal without a predator is a treadmill. Ask what the equivalent would be in the kelp forest from the connection slide (removing urchins by hand without a predator to keep them down).
4. Close on the model's limits from q9: weather, nutrients stored in the mud, zooplankton being eaten by things other than roach, the phosphorus that leaves the lake inside netted fish. A model with five rules is a thinking tool, not a forecast. That is why the real team measured every year and was ready to modify.

Recording sheet: what students fill in

Lab 3 recording sheet: Fixing Lake Vesipuro

Lake Vesipuro is a **fictional** lake, and every number here is a **teaching dataset** built to behave the way the chapter's food-web model predicts. For decades a town piped sewage into the lake. The sewage carried nutrients that fed the algae, and the water turned green and murky. Fish died in late summer when

decomposers breaking down dead algae used up the oxygen. Small plankton-eating fish called roach now swarm; big predatory fish are rare. Your team has four years and nine budget units to bring the lake back.

Baseline monitoring data, three years before the project

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

Year	Nutrient inflow score (0-10)	Roach per net-night	Predatory fish per net-night	Zooplankton per liter	Algae cells per drop	Clarity depth (m)	Dawn oxygen, late summer (mg/L)
3 years ago	8	44	2	10	950	0.8	2.3
2 years ago	8	46	1	8	1000	0.7	1.9
Last year	8	41	2	11	900	0.8	2.1

Clarity depth is how deep a white disk can be lowered before it disappears; deeper means clearer. Fish are stressed when oxygen falls below about 4 mg/L. Simulated data for a fictional lake.

1. Describe the lake's problem using at least three variables from the dataset, with their numbers.

Answer: The lake is murky and overloaded: nutrient inflow is high (8 of 10 every year), algae are dense (900 to 1,000 cells per drop), clarity is poor (0.7 to 0.8 m), zooplankton are scarce (8 to 11 per liter), roach are abundant (41 to 46 per net-night) while predatory fish are rare (1 to 2), and late-summer dawn oxygen (1.9 to 2.3 mg/L) is below the 4 mg/L fish-stress line.

Why: Any three variables with their numbers earn credit; strong answers connect them (high nutrients, dense algae, low clarity).

- At least three variables named
- Numbers quoted from the table
- Describes the problem rather than just listing

2. Write the sign chain the food-web model is betting on when it says 'fewer roach will clear the water'. Start with roach – and end with clarity.

Answer: Roach –, zooplankton +, algae –, clarity +.

Why: Fewer roach eat fewer zooplankton; more zooplankton graze more algae; fewer algae means clearer water. The sign flips at each eating link and stays at the clarity step.

- Four steps in the correct order
- Signs correct

Model rule card: apply the rules in this order, every year — Start: nutrient score $N = 8$, roach index $R = 10$. Each year: (1) **Nutrients N**: if the inflow has been diverted (built this year or earlier), N falls by 1, minimum 4; otherwise N stays. (2) **Roach R**: if roach are netted this year, $R = 3$. Otherwise $R = \text{last year's } R + 2$ (maximum 10). Then, if predatory fish were stocked in an earlier year, subtract 3 (minimum 1). (3) **Zooplankton $Z = 10 - R$** . (4) **Algae $A = N - Z \div 2$** . (5) **Clarity (m)** $= (10 - A) \times 0.4$. Then record the cost of this year's actions.

Plan menu and costs

Action	What it does in the model	Cost (units)	Notes
Divert the nutrient inflow (build a pipeline to a treatment plant)	N falls by 1 every year from the build year on, minimum 4	6, once	Slow because nutrients stored in the bottom mud keep feeding algae for years
Net out roach	$R = 3$ in each year it is done	2 per year	Roach breed fast; R regrows by 2 each year it is not done
Stock predatory fish	R falls by 3 each year starting the year after stocking	3, once	Also gives anglers something to catch by year 4 if stocked by year 2
No action	Nothing changes	0	The lake stays at $N = 8$, $R = 10$, clarity 0.8 m

Criteria (what success means): C1, clarity at least 2.0 m in year 4. C2, clarity still at least 2.0 m in year 5 with no new spending. C3, predatory fish stocked by year 2, so anglers have fish by year 4. **Constraints** (limits): K1, total cost over years 1 to 4 at most 9 units. K2, each action can be taken at most once per year.

Run sheet A (plan: _____)

Year	Actions this year	N	R	$Z = 10 - R$	$A = N - Z \div 2$	Clarity $= (10 - A) \times 0.4$	Cost
1							
2							
3							
4							
5 (no spending)	none						0

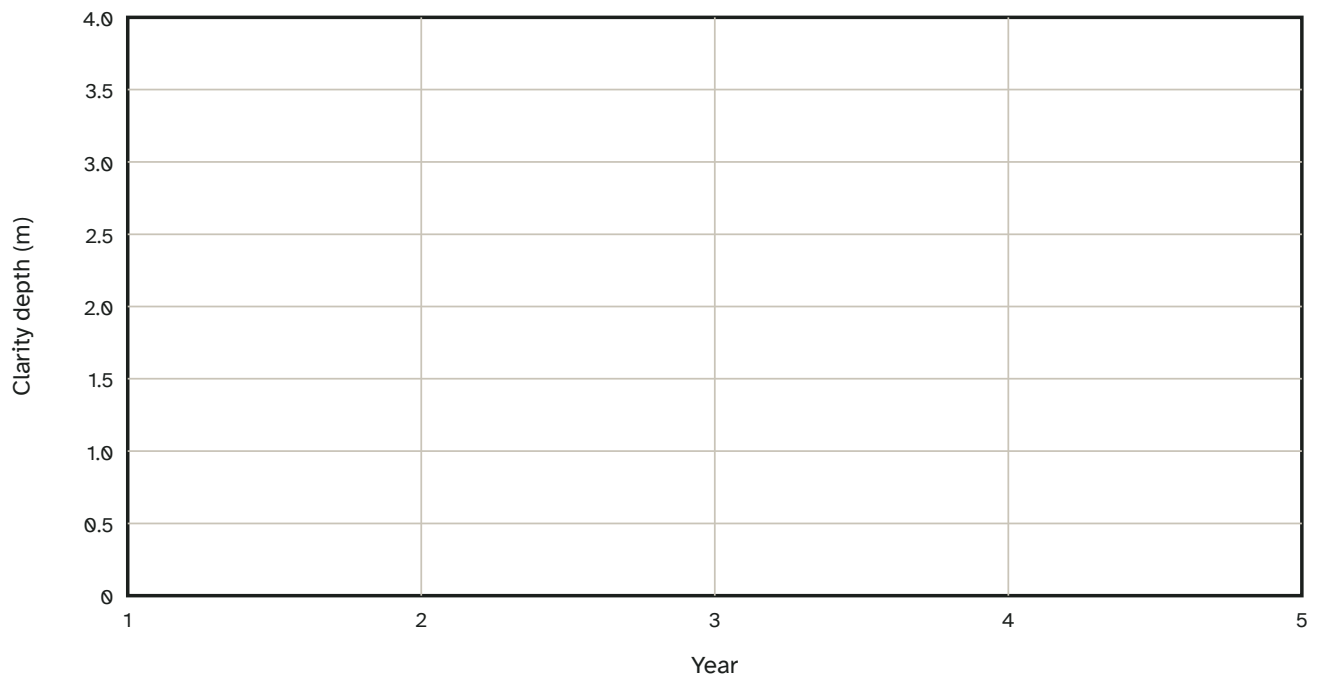
Run sheet B (plan: _____)

Year	Actions this year	N	R	$Z = 10 - R$	$A = N - Z \div 2$	$\text{Clarity} = (10 - A) \times 0.4$	Cost
1							
2							
3							
4							
5 (no spending)	none						0

Run sheet C, the modified plan (plan: _____)

Year	Actions this year	N	R	$Z = 10 - R$	$A = N - Z \div 2$	$\text{Clarity} = (10 - A) \times 0.4$	Cost
1							
2							
3							
4							
5 (no spending)	none						0

Predicted clarity depth by year for plans A, B and C



Criteria and constraints check

Plan	C1: year-4 clarity ≥ 2.0 m?	C2: year-5 clarity ≥ 2.0 m?	C3: predators stocked by year 2?	K1: total cost ≤ 9?	Criteria met (out of 3)
A					
B					
C					

3. For plans A and B, which criteria were met and which were missed? Give the year-4 and year-5 clarity numbers and the total cost for each.

Answer: Depends on the plans chosen. Reference results: net Y1 + stock Y1 (cost 5): year 4 2.6 m, year 5 2.6 m, meets C1, C2, C3, K1. Divert + stock Y1 (cost 9): year 4 3.4 m, year 5 3.6 m, meets all. Divert only (6): 2.4 and 2.4 m, fails C3. Stock only (3): 1.8 and 2.0 m, fails C1. Net Y1-Y4 (8): 2.2 and 1.8 m, fails C2 and C3. Divert + net Y1 (8): 2.6 and 2.4 m, fails C3.

Why: Check the student's numbers against the reference runs; a plan's criteria verdict must follow from its own run sheet.

- Year-4 and year-5 clarity stated for both plans
- Total cost stated
- Each criterion marked met or missed consistently with the numbers

4. What did you change to make plan C, and what miss were you trying to fix? Did the model output show the change worked?

Answer: Group-specific. Common modifications: adding a predator stocking to 'divert only' (fixes C3, cost 9, year 4 3.4 m); replacing yearly netting with one netting plus stocking (fixes C2 and C3, cost 5); moving stocking from year 2 to year 1 so the predator effect arrives a year sooner.

Why: The point is a targeted change tied to a named miss, and a check of the new output.

- Names the specific change
- Names the miss it addresses
- Reports whether the model output improved

5. Decision and justification. Which plan do you recommend? Give the numbers that show it meets each criterion and the constraint, explain why you preferred it over the others, and name one way the real lake might behave differently from the model.

Answer: Either of two well-justified decisions: (a) net Y1 + stock Y1, cost 5: year 4 2.6 m, year 5 2.6 m, predators stocked in year 1, under budget with 4 units spare for monitoring or a repeat netting; preferred for cost and speed. (b) divert + stock Y1, cost 9: year 4 3.4 m, year 5 3.6 m, predators in year 1, exactly on budget; preferred because it also removes the cause (nutrients) rather than only managing the symptom. A model limitation: real roach may rebound faster or slower, nutrients in the mud may keep feeding algae longer, weather can change algae growth, or zooplankton may be eaten by animals the model ignores.

Why: Both decisions meet every criterion and constraint; credit depends on the numbers being correct and the comparison being explicit. A decision for 'divert only' can earn partial credit only if the student acknowledges the C3 miss and argues for it.

- Names a plan that meets all three criteria and the budget, with the year-4 and year-5 numbers
- Compares against at least one other plan
- Gives a reason for the preference (cost, clarity, removing the cause, speed)
- Names one specific model limitation

Analysis questions: answer key

6. Run 'divert only' and 'net in year 1 plus stock in year 1' if your group did not already. One works through matter (less nutrient coming in) and the other through the food web (an indirect effect on algae). Compare their year-4 clarity, their cost and which criteria each meets, and explain what each one misses.

Answer: Divert only: clarity 1.2, 1.6, 2.0, 2.4 m, cost 6, meets C1 and C2 but fails C3 and leaves roach at 10 and zooplankton at 0. Net Y1 + stock Y1: clarity 2.2, 2.4, 2.6, 2.6 m, cost 5, meets all three criteria. Divert works through matter: less nutrient enters, so producers have less to build with, but it is slow and does nothing for the fish community. The food-web plan works through an indirect effect, fewer roach means more zooplankton means fewer algae, but it leaves the nutrient inflow at 8, so the lake stays loaded and depends on the predators holding the roach down forever.

Why: Students should see that the two routes attack different parts of the same system and that each leaves something undone.

- Correct year-4 clarity and cost for both
- Criteria verdicts correct
- Identifies the matter route versus the food-web route
- Names what each plan misses

7. A plan that nets roach every year for four years reaches 2.2 m every year and then falls to 1.8 m in year 5. Use the rule card to explain why, and explain the real biology the rule stands for.

Answer: In each netting year R is set to 3, so $Z = 7$, $A = 8 - 3.5 = 4.5$ and clarity = $5.5 \times 0.4 = 2.2$ m. In year 5 there is no netting, so R regrows to 5, $Z = 5$, $A = 5.5$ and clarity = $4.5 \times 0.4 = 1.8$ m. The rule stands for the fact that small plankton-eating fish breed quickly; without a predator to keep them down, the population bounces back as soon as removal stops, so netting alone is a treadmill.

Why: Full credit needs the arithmetic for a netting year and for year 5, plus the biological meaning of regrowth.

- Shows the 2.2 m calculation
- Shows the 1.8 m year-5 calculation
- Explains regrowth as fast breeding without predators

8. In the model, stocking predators alone takes until year 5 to reach 2.0 m. In the real Finnish lake the textbook describes, scientists stocked predatory fish for several years and also netted out plankton-eating fish. Using your runs, explain why doing both makes sense even though each alone has a weakness.

Answer: Stocking alone is slow because the roach regrow by 2 each year while predators remove 3, a net drop of only 1 per year, so clarity creeps up (0.8, 1.4, 1.6, 1.8, 2.0 m). Netting alone is fast but temporary. Together, netting knocks R to 3 at once and the predators then hold it down (R goes 3, 2, 1, 1), so the water clears in year 1 and stays clear without more netting. Each action covers the other's weakness: speed from netting, holding from predators.

Why: This mirrors the textbook's story and the real lake's overlapping steps. Students should use their own run numbers.

- Explains the slowness of predators alone with numbers
- Explains the relapse of netting alone
- Explains the combination with the R sequence

9. Name two things a real lake has that the model leaves out, and explain how one of them could make a plan that the model says will work fail, or a plan the model rejects succeed.

Answer: Examples: weather (a hot sunny summer can boost algae regardless of the plan); nutrients stored in the bottom mud that keep leaking out for years (so 'divert' may be even slower than the model's N decline); other animals that eat zooplankton, such as insect larvae or stocked fish fry (so more zooplankton may not follow fewer roach); the phosphorus removed inside netted fish (so netting may lower nutrients too, helping more than the model says); disease or a fish kill. Any one could make a 'working' plan fail (a hot summer undoing year-4 clarity) or a 'rejected' plan succeed (netting also exporting nutrients).

Why: Two omissions plus one worked consequence. The real review of the Finnish lake notes nutrient export in fish and the debated role of zooplankton grazing.

- Two specific omissions
- One explained consequence in either direction

10. Diverting the inflow lowers algae, and stocking predators also lowers algae, but for different reasons. Explain each using the chapter's ideas: one in terms of matter entering the system and the other in terms of direct and indirect effects.

Answer: Diversion: algae are producers, and they build their bodies from matter, especially nitrogen and phosphorus nutrients, that enters the lake in sewage and runoff. Cut the inflow and there is less matter for producers to grow with, so the algae population shrinks. Stocking predators: predatory fish eat roach (a direct effect, roach -); fewer roach eat fewer zooplankton (direct effect, zooplankton +); more zooplankton graze more algae (direct effect, algae -). The predators never touch the algae, so their effect on algae is indirect, passed through two other populations.

Why: This ties Lab 1 (matter from the environment) to Lab 1 session 2 (direct and indirect effects). Both routes reduce the same population.

- Diversion explained as less matter for producers
- Predator route written as a chain with direct and indirect labels
- States that the predator effect on algae is indirect

11. You will only know the real lake is responding by measuring. Name three measurements to make in year 1, say what result would tell you the plan is on track, and what result would make you modify the plan early.

Answer: Examples: roach per net-night (on track if it drops well below 40 within a year; modify if it stays near 40); zooplankton per liter (on track if it rises above about 20; modify if it stays near 10 even after roach fall, which would suggest something else is eating zooplankton); algae cells per drop and clarity depth (on track if algae fall below about 600 and clarity passes 1.2 m; modify if clarity does not move); dawn oxygen (on track if it rises above 4 mg/L). Also nutrient inflow if diversion was built.

Why: Measurements should match the variables in the model and come with a decision rule in both directions.

- Three measurements named
- An on-track value or direction for each
- A modify-early result for at least one, with a reason

Individual evidence of learning

Each student submits their own run sheets A, B and C, the clarity graph, the criteria table, and answers to q1 through q11. The run sheets and criteria table are evidence of using a model to generate data for iterative testing; q5 is the evidence-based argument; q9 and q10 show understanding of model limits and of the matter-versus-food-web routes to the same outcome.

Assessment criteria

Criterion	Proficient looks like
Model use	All three run sheets complete and arithmetically correct with rules applied in order; year-5 row computed with no spending.
Iteration	Plan C changes something specific in response to a named miss in plan A or B, and the student says whether the output confirmed the change.
Evidence-based decision	The justification cites year-4 and year-5 clarity, cost and the predator criterion with numbers, compares at least two plans, and names a model limitation.
Matter and food-web reasoning	Explains that nutrient diversion reduces the matter available to producers while predator stocking reduces algae through an indirect effect (q10).
Monitoring plan	Names three sensible measurements with an on-track result and a modify-early result for each (q11).

Accessibility adaptations

- Provide run sheets with year 1 of each plan already computed, and a laminated copy of the rule card with the five steps numbered in large print.
- Allow a calculator app that shows the running expression, and accept a spoken justification for q5 recorded on a device.
- Pair a student who struggles with multistep arithmetic as the accountant (tracking cost and criteria) with a confident modeler, and swap roles for plan C.

- Offer the sign-chain sentence frame for q2 and q10: 'Fewer ___ means more ___, which means fewer ___, so ___.'

Low-cost alternative

No materials beyond printing are needed. If printing is limited, project the rule card and plan menu and have students draw the run sheets in their notebooks with eight columns.

Model limitations

Lake Vesipuro is fictional and every number is simulated; the five rules were written so that the plans behave the way the chapter's food-web model predicts, and they use whole-number indices rather than real population measurements. The real lake the textbook describes recovered through a messier history in which sewage diversion did much of the work and the fish steps overlapped, and the researchers themselves do not treat extra zooplankton grazing as the proven cause of the algae decline. The model leaves out weather, nutrients stored in the bottom mud (beyond the slow N decline), other predators of zooplankton, the phosphorus removed inside netted fish, and chance. Use it to practice test-measure-modify, not to predict any real lake.

Teacher notes

Reference runs (N, R, Z, A, clarity by year): net Y1 + stock Y1: Y1 8,3,7,4.5,2.2; Y2 8,2,8,4.0,2.4; Y3 8,1,9,3.5,2.6; Y4 8,1,9,3.5,2.6; Y5 same. Divert + stock Y1: Y1 7,10,0,7,1.2; Y2 6,7,3,4.5,2.2; Y3 5,6,4,3.0,2.8; Y4 4,5,5,1.5,3.4; Y5 4,4,6,1.0,3.6. Divert only: Y1 7,10,0,7,1.2; Y2 6,10,0,6,1.6; Y3 5,10,0,5,2.0; Y4 4,10,0,4,2.4; Y5 same. Stock only: Y1 8,10,0,8,0.8; Y2 8,7,3,6.5,1.4; Y3 8,6,4,6.0,1.6; Y4 8,5,5,5.5,1.8; Y5 8,4,6,5.0,2.0. Net every year: 8,3,7,4.5,2.2 for Y1-Y4; Y5 8,5,5,5.5,1.8. Divert + net Y1: Y1 7,3,7,3.5,2.6; Y2 6,5,5,3.5,2.6; Y3 5,7,3,3.5,2.6; Y4 4,9,1,3.5,2.6; Y5 4,10,0,4.0,2.4. Grade q5 on the match between the numbers and the verdicts, not on which plan was chosen.