

Keep the Mussels Out: Designing a Boat Check for a Reservoir

Learning target: I can turn vague goals into precise criteria and constraints, evaluate competing plans for stopping an invasive species with a simple model, and design and justify a better plan within a budget.

Transfer and design

About 55 min

Pairs

MS-LS2-5 · assesses

MS-ETS1-1 · assesses

MS-ETS1-2 · assesses

engineering design

data analysis

writing

Name _____

Date _____

Period _____

Directions

You and a partner are consultants to a water district. Read the situation, then work in order. Part A: make the goals precise. Part B: run the two competing plans through the model and check them against the criteria. Part C: design your own plan and defend it. Part D: test your criteria and plan how to monitor. All costs and effects are teaching estimates for an invented reservoir. Each partner writes their own q6 and q7.

You will need: This worksheet, Pencil, Calculator

The situation

Quagga and zebra mussels are small freshwater mussels native to the region around the Black and Caspian Seas. They reached the Great Lakes in the late 1980s, probably in ships' ballast water, were found in Lake Mead, Nevada, in 2007, and have since spread to some California reservoirs, through aqueducts carrying Colorado River water and on trailered boats moved between lakes. Adults can live for days out of water in a damp corner of a boat, and their larvae are too small to see. Once they take hold, they filter huge amounts of plankton out of the water, leaving less food for the small animals and young fish at the base of the food web. They crust over rocks, docks and the shells of native mussels, and they clog the pipes that carry water to treatment plants and power stations. No one has yet found a way to remove them from a large lake.

Sierra Vista Reservoir (invented for this worksheet) stores drinking water for 200,000 people, feeds a small hydropower plant and supports a trout fishery and native fish. It has about 20,000 boat launches each summer and no mussels yet. The district estimates that, with no prevention, about **12 boats carrying live mussels** would arrive each summer.

What the district board said — 'Keep the mussels out.' 'Don't ruin summer for visitors.' 'Know quickly if they get in anyway.' 'Don't make people who did nothing wrong lose their trip.' 'Stay within our money.' The board has \$400,000 a year for prevention and will not allow chemicals in the lake that could harm native fish.

Parts a prevention plan can include (teaching estimates)

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

Part	Cost per summer	Effect in the model	Effect on visitors
A. 'Clean, Drain, Dry' signs and campaign	\$10,000	1 in 4 boats that would have arrived with mussels arrive clean instead	None
B. Inspection station on the entrance road, open 6 a.m. to 8 p.m.	\$220,000	Inspectors find 9 of every 10 boats with mussels that they check and miss 1 in 10	Average weekend wait of 25 minutes
C. Gates that lock the ramps when the station is closed (needs B)	\$40,000	Without gates, 1 in 3 boats with mussels arrives after hours and launches uninspected; with gates, none do	Late arrivals wait until morning
D. Hot-water cleaning unit (needs B)	\$90,000	Boats found with mussels are cleaned and may launch; without D they are turned away	Boats that are cleaned wait about 40 minutes more
E. Monitoring: sampling plates and larva samples every two weeks	\$30,000	Stops no boats, but would find a new mussel population within a year instead of after about three years	None
F. Second inspection crew (needs B)	\$80,000	Same checking as B	Average weekend wait drops from 25 to 10 minutes

Simulated data for teaching. The costs and effects are invented. Hot-water cleaning at about 60 °C is a real method used to kill mussels on boats.

1. Start with 12 boats carrying live mussels in one summer. With part A, multiply by 0.75.
2. Without part B, every one of those boats launches.
3. With B but without C, one third of the arriving boats come after hours and launch uninspected. With C, none do.
4. All other arriving boats are inspected. Missed boats = inspected boats $\times$ 0.1.
5. Contaminated launches = boats that skipped inspection + boats the inspectors missed. Boats that are found are either cleaned (D) or turned away; either way they do not launch with live mussels.

Two competing plans

Plan	Proposed by	Parts
Plan 1	The boaters' club	A + B + F
Plan 2	The water district staff	A + B + C + D + E

Part A: Make the goals precise

1. Rewrite each board statement as a precise criterion (a goal with a number or test) or a constraint (a firm limit). Label which it is.

Criterion or constraint?	Precise version
'Keep the mussels out.'	
'Don't ruin summer for visitors.'	
'Know quickly if they get in anyway.'	
'Don't make people who did nothing wrong lose their trip.'	
'Stay within our money' and 'no chemicals in the lake'	

The criteria the board adopted (use these for Parts B and C) — C1 (scientific): on average, fewer than 1 boat with live mussels launches per summer. **C2 (social):** average weekend wait at the entrance of 20 minutes or less. **C3 (scientific):** a monitoring program that would find a new mussel population within one year. **C4 (economic and social):** boats found with mussels are cleaned so visitors can still launch, instead of being turned away. **Constraints:** cost no more than the money available, which is the board's \$400,000 per summer unless a plan raises more (Part C allows one way to do that); no chemicals in the lake.

Part B: Evaluate the competing plans

2. Run both plans through the model. Show the numbers in each box.

Plan 1 (A + B + F)	Plan 2 (A + B + C + D + E)
Total cost per summer	
Boats with mussels arriving	
Boats that skip inspection	
Boats inspected	
Boats the inspectors miss	
Contaminated launches per summer	
Average weekend wait	
Found boats: cleaned or turned away?	
Monitoring in place?	

3. Check each plan against the criteria and the budget. Write pass or fail and the number or fact that decided it.

C1	C2	C3	C4	Budget
Plan 1				
Plan 2				

4. Plan 1 includes an inspection station, yet it lets far more mussel boats through than Plan 2. Which missing part causes most of the difference? Use your numbers.

Part C: Design a better plan

5. Design Plan 3. Choose your parts and run it through the model. You may add **one** way to raise more money (for example, an inspection fee per launch), but you must calculate how much it raises using the 20,000 launches per summer.

Plan 3
Parts chosen (and any fee)
Total cost and money available
Contaminated launches per summer
Average weekend wait
Found boats: cleaned or turned away?
Monitoring in place?
Criteria passed (C1-C4)

6. Write your recommendation to the board. Explain why Plan 3 is better than Plans 1 and 2, using at least one scientific reason (about the reservoir's food web, native species or water supply), one economic reason and one social reason. Use numbers from the model.

7. Name the tradeoff in your plan: which criterion did you meet less well, or who pays more, and why is that acceptable? If you used a fee, explain who pays it and whether it is fair.

Part D: Test the criteria and plan to monitor

8. Plan 2 lets an average of 0.9 contaminated boats launch per summer. At that rate, about how many contaminated launches would there be over 10 summers? Is C1 precise and strict enough to protect a lake that mussels can never be removed from? Propose a better version of C1.

9. Write a monitoring and revision plan for your Plan 3. Name at least three things to measure (at least one about the inspection itself and one about the reservoir), how often, and one result that would make the district change the plan, with the change it would make.

Work the model one line at a time

Write the five model steps down the side of your page and fill in a number after each one. Example for a plan with only B: start 12; no A, so 12 arrive; no C, so $12 \div 3 = 4$ skip; $12 - 4 = 8$ inspected; $8 \times 0.1 = 0.8$ missed; contaminated launches = $4 + 0.8 = 4.8$. For q1, ask 'How would we know?' and put a number or a yes-or-no test in every answer.

What the model leaves out

The model treats every inspection as equally good and every summer as the same. List three things in the real world that could make the model wrong (for example, tired inspectors on busy weekends, boats arriving by an unguarded dirt road, or a rise in visitors from a lake that already has mussels). For one of them, change a number in the model, rerun your Plan 3, and explain whether your recommendation still holds.