

Listening Past the Highway: Choose a Shield for the Frog Recorders

Learning target: I can turn vague goals into precise criteria and constraints, evaluate competing designs against them with test data, choose and justify a design, and explain how accurate monitoring lets scientists test a prediction about how two species interact.

Transfer and design

About 55 min

Pairs

MS-ETS1-2 · practice

MS-ETS1-1 · practice

MS-LS2-2 · assesses

engineering design

data analysis

writing

Name _____

Date _____

Period _____

Directions

You are advising the biologists who run the Cedar Flat frog-monitoring project. Read the problem, the sound facts and the team's first ideas. In Part A, turn the vague goals into precise criteria and constraints. In Part B, use the field test data to score four shield designs in a decision matrix. In Part C, choose a design, justify it with numbers, and explain what the corrected frog counts should show. All numbers on this sheet are teaching data, invented to be realistic; they are not measurements from a real project.

You will need: This worksheet, Pencil, Calculator

The problem

Cedar Flat is a group of five small ponds in the California foothills, each 50 to 150 meters from a four-lane highway. Biologists monitor the ponds' Sierran treefrogs, small native frogs often called chorus frogs, with sound recorders. Each recorder sits on a short post at the pond's edge and switches on every night from January to April, the calling season. Software counts the frog calls in each recording, which tells the team roughly how many males are calling at each pond. The trouble is the highway. Truck and tire noise covers up many of the calls, so the software misses them. Two years ago, American bullfrogs were found in two of the ponds. Bullfrogs are large frogs, not native to California, that eat almost any animal that fits in their mouths, including treefrogs, and they also eat the same insects the treefrogs eat. The team needs accurate counts to find out whether the bullfrogs are pushing the treefrogs down.

Sound facts that limit the possible solutions — Sound spreads out from its source in all directions and bends around the edges of obstacles, so a shield works best when it blocks the straight line between the highway and the recorder and has no gaps. Heavy, solid, airtight materials such as wood, packed straw or dense board are best at blocking sound, including low-pitched rumble. Soft, porous materials such as foam, felt or blankets soak up sound, especially high-pitched sound, but let more of the low rumble through. The shield cannot surround the recorder completely, because the frog calls come from the pond side. Sound levels are measured in decibels (dB): each drop of about 3 dB cuts the sound energy roughly in half, and a drop of about 10 dB sounds roughly half as loud to a listener.

Part A: Make the goals precise

At its first meeting, the team wrote four goals on the whiteboard: **'Make it quieter.'** **'Don't mess up the frog sound.'** **'Keep it cheap and easy to carry.'** **'It can't hurt anything.'** Goals like these are a start, but nobody can test them, because they do not say how much, measured how, or compared with what.

1. Decide whether each goal is a criterion (what the design must do to succeed) or a constraint (a limit on what designs are allowed), then rewrite it so it can be tested.

Criterion or constraint?	Precise, testable version (include a number, a unit and how it would be measured)
'Make it quieter.'	
'Don't mess up the frog sound.'	
'Keep it cheap and easy to carry.'	
'It can't hurt anything.'	

The team's final list — Criteria. C1: highway noise at the recorder at least 8 dB lower than with no shield (tested with a recorded traffic sound played from the highway side). C2: frog calls played from the pond side no more than 2 dB quieter than with no shield. C3: the software detects at least 70 of 100 test frog calls played from the pond side during evening traffic. C4: after a 30-minute sprinkler 'rain test', the highway noise at the recorder rises by no more than 2 dB. **Constraints.** K1: no more than \$100 per shield, and \$500 for all five ponds. K2: no more than 15 kg, so one person can carry it along the pond trail. K3: no plastic netting or loose mesh, which can trap snakes, frogs and birds. K4: everything stays within 1 m of the recorder post on the dry, highway side, leaving the water and the pond-edge plants untouched.

2. Compare your four rewrites with the team's final list. Name one place where one version is more precise than the other, and explain why that matters for testing. Then add one more constraint the team missed that protects people or wildlife, and give the reason for it.

Part B: Evaluate four designs

Four prototype shields (teaching dataset)

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

Design	What it is	Cost per shield (\$)	Mass (kg)	Field notes
A: Foam-lined box	Plywood box with a roof and acoustic foam inside, open only on the pond side	85	9	Foam stays dry under the roof
B: Straw-bale wall	Three straw bales stacked 1.2 m tall, 1 m behind the recorder on the highway side	40	75	About 25 kg per bale; straw rots within about a year
C: Blanket tent	Moving blankets draped over a tent-pole frame on three sides	30	4	Wet blankets sag and open gaps
D: Mesh-and-foam cone	Foam sheets held in a cone shape by plastic garden netting, open to the pond	60	6	Loose netting edges hang near the ground

Simulated descriptions and costs for teaching. Mass is the total a person would have to carry to the pond.

Field test results at one pond (teaching dataset)

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

Setup	Highway noise at recorder (dB)	Pond-side frog calls at recorder (dB)	Test calls detected (of 100)	Highway noise after rain test (dB)
No shield	64	58	41	—
A: Foam-lined box	52	57	88	53
B: Straw-bale wall	56	58	74	56
C: Blanket tent	58	55	66	61
D: Mesh-and-foam cone	50	56	90	51

Simulated test results for teaching. The same traffic recording and the same 100 test frog calls were played for every design.

3. Complete the decision matrix. Calculate each value from the tables (for C1, subtract the design's highway reading from the no-shield reading; for C2, subtract its pond-side reading from 58 dB; for C4, subtract its normal highway reading from its after-rain reading). A design that breaks any constraint is eliminated, no matter how well it scores.

C1: noise cut in dB (pass/fail)	C2: frog-call loss in dB (pass/fail)	C3: calls detected (pass/fail)	C4: rise after rain in dB (pass/fail)	Constraint broken, if any	Keep or eliminate?
Design A					
Design B					
Design C					
Design D					

4. Use the 3 dB rule from the sound facts. Design A lowers the highway noise from 64 dB to 52 dB, and Design C lowers it from 64 dB to 58 dB. For each design, how many halvings of sound energy is that, and about what fraction (and percent) of the highway's sound energy still reaches the recorder? How many times more highway sound energy gets through Design C than Design A?

5. Design D scored best on every criterion, yet it is eliminated. Explain why a broken constraint knocks a design out even when it performs best, and describe the real harm that constraint prevents.

Part C: Decide, justify and predict

6. Recommend one design for all five ponds. Justify it with at least three numbers from the test data, show the total cost for five shields, and describe one trade-off: something your choice does less well than another design.

7. Traffic on the highway has grown every year. Explain how unshielded recorders could make it look as if the bullfrogs were harming the treefrogs even if they were not, and why the shield is needed before the team can draw any conclusion.

8. With shields in place, the team will follow three kinds of ponds for three calling seasons: (a) ponds where bullfrogs are present, (b) ponds with no bullfrogs, and (c) a pond where the team removes every bullfrog this year. Name the interaction or interactions between bullfrogs and treefrogs and rate each species. Then predict what the treefrog call counts should show in each kind of pond, including whether any change should appear right away or after a delay. Support your prediction with the same pattern in at least one other ecosystem you have studied.

Pass or fail first, then compare

Work one row of the matrix at a time. Noise cut = 64 minus the design's highway reading. Frog-call loss = 58 minus its pond-side reading. Rain rise = its after-rain reading minus its normal highway reading. Write the number, then 'pass' or 'fail' beside it. Next, read the design's cost, mass and field notes and check K1 to K4. Only the designs with no broken constraint stay in the running; compare those using the numbers. For q4, count halvings by dividing the dB drop by 3, then multiply $\frac{1}{2}$ by itself that many times.

Combine the best features

Design D performed best but broke a constraint, and Design B was cheap but far too heavy. Sketch a new design that keeps D's cone shape and foam but holds them with an allowed material, or that packs B's solid mass into something one person can carry. List its materials and estimated cost, predict its test results compared with Design A, say which prediction you are least sure of and why, and describe the one field test you would run first.