

# Bring Back the Forest: Choosing a Restoration Plan for Driftwood Cove

**Investigation question: Which plan, or combination of plans, can bring back Driftwood Cove's kelp forest and its species within ten years, on a fixed budget, with enough community support to go ahead?**

Data-driven decision

Groups of 4

2 sessions

Setup 5 · Activity 90 · Cleanup 5 min

MS-LS2-5 · assesses

MS-ETS1-3 · practice

MS-ETS1-2 · practice

## Scientific purpose

Students evaluate three competing plans for restoring a fictional urchin barren, each backed by simulated projection data: divers removing urchins, releasing captive-raised sunflower sea stars, and returning sea otters. They mark each plan pass or fail against criteria for kelp cover, fish species and timing and against budget and community-support constraints, discover that no single plan passes everything, and design a hybrid that keeps the best characteristic of each. A results card shows how their hybrid would perform; they may modify it once, then commit to a decision and defend the trade-off they accept.

## Why this helps students with this chapter

Real conservation choices rarely have a single winner. Scoring every plan against the same criteria shows students that a plan can be excellent on one measure and still fail, that community support is a real constraint rather than a matter of taste, and that combining parts of plans is often the best design move, as the lesson's engineers did with a gecko texture and a mussel glue. The plan that works worst alone turns out to be part of the strongest combination, which teaches students to read the data instead of ranking plans by first impressions.

## Standards connections

**MS-LS2-5** (assesses, evaluating competing design solutions for maintaining biodiversity and ecosystem services against agreed criteria and constraints): Students evaluate three restoration plans and their own hybrid against criteria for kelp cover and fish species richness (biodiversity), weigh the abalone fishery and visitor businesses (ecosystem services), and apply constraints that are scientific (uncertain predator survival), economic (a fixed budget) and social (community support). The scorecards, hybrid design and written justification are direct evidence toward this Grade 7 PE.

**MS-ETS1-3** (practice, analyzing data on several solutions to combine their best characteristics into a new solution): Students use projection data to find each plan's best characteristic (speed, staying power, low cost) and combine them into a hybrid that they check against the criteria, mirroring the lesson's gecko-and-mussel adhesive. The data are simulated rather than gathered from students' own tests, so this is practice.

**MS-ETS1-2** (practice, using a systematic process to judge how well competing solutions meet criteria and constraints): The pass-or-fail scorecard applies the same five tests to every plan and hybrid. The evaluation process is supplied rather than designed by students, so the lab practices this PE.

## Roles (rotate each session)

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- **Data reader:** Reads the projections aloud and checks every pass or fail mark against the actual numbers.
- **Budget keeper:** Totals the cost of every plan and hybrid over years 1 to 10 and checks it against the 60-point constraint.
- **Community advocate:** Speaks for the people affected (shellfish divers, dive and kayak businesses, coastal residents), tracks the support constraint and keeps the abalone numbers in the discussion.
- **Spokesperson:** Drafts the group's final justification from the recorded numbers and presents the decision to the class.

## Materials

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| Item                                                                                        | Quantity | Per     | Note |
|---------------------------------------------------------------------------------------------|----------|---------|------|
| Recording sheet with the background, plan cards, projection datasets and scorecards         | 1        | student |      |
| Hybrid results card, printed separately and handed out after each group commits to a design | 1        | group   |      |
| Calculator                                                                                  | 1        | group   |      |
| Colored pencils for the kelp graph (one color per plan)                                     | 3        | group   |      |
| Sticky notes for the class gallery of final choices                                         | 1 pad    | group   |      |

**Estimated cost:** 2 to 4 per class (an estimate; Estimate for printing only. Calculators, colored pencils and sticky notes are classroom stock.)

## Safety

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- Paper-and-pencil activity with no physical hazards.
- The cove, the costs, the community survey and every projection are fictional. When students talk about real groups, such as shellfish divers or tribes with long ties to the coast, keep the discussion respectful and avoid claiming to know real people's positions.

## Teacher preparation and setup

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1. Print the recording sheet for every student. Print the hybrid results card separately for each group (it also appears at the end of the sheet as a reference copy; fold that page back or remove it) and hold the cards until each group has written down a committed hybrid design.
2. Work through the single-plan scorecard and the results card yourself using the answer key's teacher notes. The most common misreading is taking plan A's year-5 kelp (40 percent) as its final result and missing that it falls to 12 percent by year 10 after the divers stop.
3. Post the criteria and constraints where every group can see them: C1 kelp canopy at least 25 percent by year 5; C2 kelp canopy at least 25 percent in year 10; C3 at least 14 kelp-forest fish species in year 10; K1 total cost at most 60 points over years 1 to 10; K2 at least 50 percent community support.

4. If students did Lab 2, remind them that Driftwood Cove is the barren they diagnosed and that clue 4 described what otters eat. If not, the background on the sheet is enough to start.

## Investigation design

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|                             |                                                                                                                                                                                                                                                                                                    |
|-----------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Independent variable</b> | The restoration plan or hybrid: which actions (urchin removal by divers, sea star release, sea otter return, the shellfish support step) are used and for how many years.                                                                                                                          |
| <b>Dependent variable</b>   | Projected kelp canopy from year 0 to year 10, kelp-forest fish species, red abalone and purple urchin density, total cost and community support.                                                                                                                                                   |
| <b>Controlled</b>           | Same starting conditions for every plan: 3 percent kelp, 48 urchins per m <sup>2</sup> , 8 fish species, 6 red abalone per 100 m <sup>2</sup> ; Same criteria, constraints and budget for every group; Same projection data and results card for every group; Costs counted over the same 10 years |
| <b>Trials</b>               | Each group scores three single plans and at least one hybrid, with one optional modification; the class compares final choices across groups.                                                                                                                                                      |
| <b>Comparison</b>           | Every plan is compared with the no-action projection and against the same three criteria and two constraints.                                                                                                                                                                                      |

## Student procedure

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1. Session 1. Read the background and the plan cards. In q1, name the ecosystem services Driftwood Cove has lost and who has lost them.
2. Read the projection datasets. For each single plan, the Data reader finds kelp canopy in years 5 and 10 and fish species in year 10, the Budget keeper totals the cost, and the Community advocate finds the support. Fill the single-plan scorecard with pass or fail for C1, C2, C3, K1 and K2, including plan C with the shellfish support step.
3. Graph kelp canopy against year for plans A, B and C in three colors and draw a line across the graph at 25 percent.
4. Answer q2 and q3: which single plan comes closest, and what is the best characteristic of each plan that is worth keeping?
5. Session 2. Design a hybrid using parts of at least two plans: you may run urchin removal for fewer years, add the shellfish support step to an otter plan, or combine any plans. Check the cost against K1 before committing. Write the design and your predicted pass or fail marks in the hybrid design table and answer q4.
6. When your design is committed in writing, collect the hybrid results card. Find the row that matches your hybrid (or the closest one), complete the results rows of the design table, and compare them with your predictions (q5).
7. If your hybrid fails a criterion or constraint, you may modify it once and look up the new row in the Hybrid 2 column.
8. Decide. Write the group's final choice and justification (q6), including the trade-off you accept and the biggest uncertainty. Present in under two minutes, post your choice on a sticky note, and listen for what groups that chose differently valued. Answer the analysis questions individually.

## Expected observations

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- Single plans: A passes C1 (40 percent), K1 (35) and K2 (80 percent) but fails C2 (12 percent) and C3 (10 species). B passes C2 (28 percent), C3 (14), K1 (40) and K2 (70 percent) but fails C1 (15 percent). C fails C1 (6), C2 (20), C3 (12) and K2 (35 percent); with the support step it passes K2 (55 percent, cost 40) but still fails all three criteria.
- No single plan passes everything, so every group must design a hybrid.
- On the results card only H3 (removal years 1-2 + otters + support step, 54 points) passes all five; H1 misses C1 (22 percent), H2 and H4 exceed the budget (61), H5 fails support (40 percent), H6 fails C1 and the budget, and H7 fails the budget (70).
- Groups that weigh abalone heavily often argue for H1 or H2 and propose changing the budget or the year-5 target; good arguments acknowledge that this changes the agreed criteria or constraints.

## Likely difficulties

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- Reading only year 5 for plan A and calling it a success; insist on checking year 10 (12 percent) as well.
- Adding costs incorrectly for partial removal: removal costs 7 points for each year it runs (2 years = 14, 3 years = 21).
- Forgetting that the shellfish support step adds 10 points and applies only to plans with otters.
- Wanting to change the criteria after seeing the results. Allow the argument, but ask the group to say plainly that they are changing an agreed criterion and why, rather than bending it quietly.
- Treating the projections as certain. Return to each plan card's main uncertainty.

## Structured debrief

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1. Gather every group's final choice on the board with its cost, kelp in years 5 and 10, and abalone. Usually two camps appear: H3 (removal plus otters plus the support step), the only option on the card that passes every criterion and constraint, and H1 or H2 (removal plus sea stars), which keep far more abalone and higher support but miss C1 by 3 points or the budget by 1 point. Ask each camp what it valued. Both are defensible; this is the trade-off the standard asks students to evaluate.
2. Ask why plan C alone did so badly while otters anchor the best hybrid. Connect to research from Monterey Bay: after the urchin boom, otters ate many more urchins but mostly plump ones near remaining kelp, which helped those forests resist being grazed but did little to clear existing barrens. Removing urchins first gives the otters something to defend.
3. Discuss the support constraint. Note that the U.S. Fish and Wildlife Service's 2022 report to Congress found that returning sea otters to northern California and Oregon could be feasible and beneficial but could affect some shellfish fisheries, and that it recommended working with affected communities and starting with small, monitored steps. Ask what the shellfish support step stands for in real life.
4. Close on monitoring: no projection is certain. Each group names its early-warning measurement (q11), and the class agrees that a real plan would be reviewed and modified as data came in, just as the lesson's engineers retested their adhesive.

## Recording sheet: what students fill in

### Lab 3 recording sheet: Bring Back the Forest

Driftwood Cove is a **fictional** cove on the California coast where purple urchins grazed a kelp forest down to bare rock. Today the cove has 3 percent kelp canopy, 48 urchins per m<sup>2</sup>, only 8 kinds of kelp-forest fish and 6 red abalone per 100 m<sup>2</sup>. Most of its **ecosystem services** are gone: young rockfish once sheltered in the kelp, red abalone fed on drifting kelp and supported a harvest, and dive and kayak businesses brought visitors. A coastal partnership has money for one 10-year plan. Every number below is a **teaching dataset**: the three kinds of plan are real ideas being studied on the Pacific coast, but these results are projections invented for this lab.

#### Plan cards

| Plan                                     | What it does                                                                                               | Cost (points)                                                                   | Community support                     | Main uncertainty                                                                                                                   |
|------------------------------------------|------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|---------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|
| A. Urchin removal                        | Divers remove purple urchins by hand every year for years 1 to 5, then stop.                               | 7 per year of removal (35 for years 1-5)                                        | 80%                                   | Urchins crawl and drift back in from nearby barrens once removal stops.                                                            |
| B. Sea star return                       | Raise sunflower sea stars in an aquarium lab and release them in years 1 to 3; they eat urchins.           | 20 to set up breeding in year 1, plus 2 per year to monitor (40 total)          | 70%                                   | The wasting disease could return, and captive-raised stars may not survive well.                                                   |
| C. Sea otter return                      | Move a small group of sea otters from the central coast in year 1, then monitor them.                      | 10 to capture, check and move the otters, plus 2 per year to monitor (30 total) | 35%                                   | Otters may swim away; they eat abalone, crabs and urchins that divers harvest, and mostly skip thin, starved urchins on bare rock. |
| Shellfish support step (optional add-on) | A fund and monitoring program for abalone, crab and urchin divers, added to any plan that includes otters. | 10 extra                                                                        | Raises an otter plan's support to 55% | Works only while the fund lasts.                                                                                                   |

**Criteria** (what success means): **C1** kelp canopy at least 25 percent by year 5. **C2** kelp canopy at least 25 percent in year 10. **C3** at least 14 kinds of kelp-forest fish in year 10 (there were 17 before the collapse).

**Constraints** (limits): **K1** total cost at most 60 points over years 1 to 10. **K2** at least 50 percent community support, or the plan cannot get its permits.

### Projected kelp canopy (% of the cove's area) for each single plan

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

| Plan                          | Year 0 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 10 |
|-------------------------------|--------|--------|--------|--------|--------|--------|---------|
| No action                     | 3      | 3      | 3      | 3      | 3      | 3      | 4       |
| A. Urchin removal (years 1-5) | 3      | 15     | 30     | 38     | 40     | 40     | 12      |
| B. Sea star return            | 3      | 3      | 5      | 8      | 11     | 15     | 28      |
| C. Sea otter return           | 3      | 3      | 3      | 4      | 5      | 6      | 20      |

Teaching dataset: model projections for a fictional cove, not measurements.

### Other projected measures for each single plan

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

| Plan                          | Fish species, year 5 | Fish species, year 10 | Red abalone per 100 m <sup>2</sup> , year 10 | Purple urchins per m <sup>2</sup> , year 10 |
|-------------------------------|----------------------|-----------------------|----------------------------------------------|---------------------------------------------|
| No action                     | 8                    | 8                     | 3                                            | 46                                          |
| A. Urchin removal (years 1-5) | 14                   | 10                    | 8                                            | 30                                          |
| B. Sea star return            | 11                   | 14                    | 14                                           | 10                                          |
| C. Sea otter return           | 9                    | 12                    | 3                                            | 22                                          |

Teaching dataset. Year-0 values for every plan: 8 fish species, 6 red abalone per 100 m<sup>2</sup>, 48 urchins per m<sup>2</sup>.

#### 1. Name two ecosystem services Driftwood Cove has lost, and for each one say who has lost it.

**Answer:** Any two, each with who lost it: shelter for young fish such as rockfish (lost by people who fish and by the fish-eating animals of the coast); food for red abalone and the abalone harvest (lost by abalone divers and by people who value abalone culturally); a place for diving, kayaking and wildlife watching (lost by local businesses and visitors); food for other kelp-forest animals.

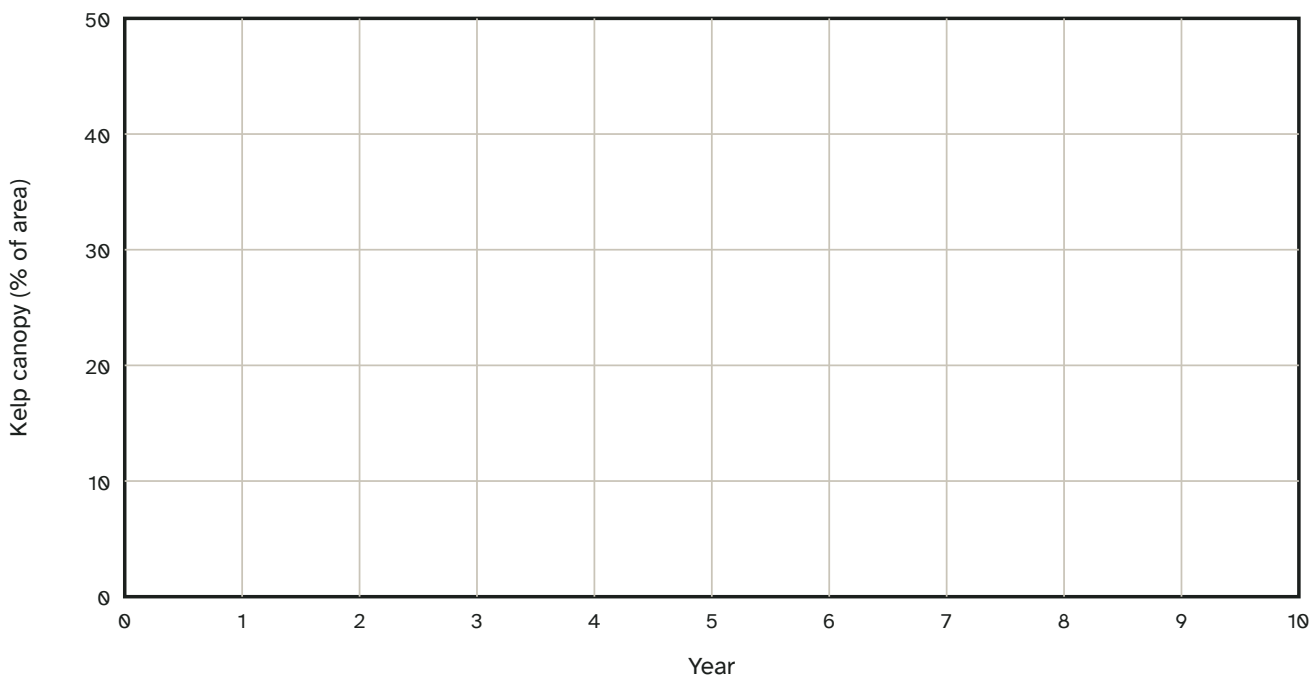
**Why:** Ecosystem services are benefits people receive; each must be linked to a group that receives it.

- Two genuine ecosystem services
- A group of people who lost each one

Single-plan scorecard (write pass or fail and the number that decides it)

| Plan                          | C1: kelp ≥ 25% by year 5 | C2: kelp ≥ 25% in year 10 | C3: ≥ 14 fish species in year 10 | K1: cost ≤ 60 | K2: support ≥ 50% | Passes all? |
|-------------------------------|--------------------------|---------------------------|----------------------------------|---------------|-------------------|-------------|
| A. Urchin removal             |                          |                           |                                  |               |                   |             |
| B. Sea star return            |                          |                           |                                  |               |                   |             |
| C. Sea otter return           |                          |                           |                                  |               |                   |             |
| C plus shellfish support step |                          |                           |                                  |               |                   |             |

Projected kelp canopy for plans A, B and C



2. Which single plan comes closest to passing everything? Which criteria or constraints does each plan fail, and by how much?

**Answer:** Plan B comes closest: it passes C2 (28 percent), C3 (14 species), K1 (40 points) and K2 (70 percent) and fails only C1 (15 percent, 10 points short). Plan A passes C1 (40), K1 (35) and K2 (80) but fails C2 (12, 13 short) and C3 (10 species, 4 short). Plan C fails C1 (6, 19 short), C2 (20, 5 short), C3 (12, 2 short) and K2 (35 percent, 15 short); with the support step it passes K2 (55 percent) at a cost of 40 but still fails all three criteria.

**Why:** Each mark follows directly from the projection tables and plan cards.

*Also acceptable: Arguing that A is 'closest' because it passes the fast criterion is acceptable only if the student correctly lists its two failed criteria.*

- Identifies B as closest
- Correct pass or fail for each plan
- States the size of each miss

3. Name the best characteristic of each plan, the one worth keeping in a combination, and the data that shows it.

**Answer:** A: speed; kelp reaches 30 percent by year 2 and 40 percent by year 5. B: staying power and abalone; kelp keeps rising to 28 percent in year 10 and abalone recover to 14. C: low cost and long-term urchin control once kelp exists; cheapest plan (30 points), and otters keep urchins down over time (48 to 22 per m<sup>2</sup>) even though they barely touch a bare barren.

**Why:** Students should name a characteristic that the data supports for each plan, not just restate the plan.

- One characteristic for each plan
- A supporting number for each

#### Hybrid design table

|                                                   | Hybrid 1 (first design) | Hybrid 2 (after one modification, if needed) |
|---------------------------------------------------|-------------------------|----------------------------------------------|
| Parts used and years                              |                         |                                              |
| Cost calculation                                  |                         |                                              |
| Community support                                 |                         |                                              |
| Predicted C1 / C2 / C3 (pass or fail)             |                         |                                              |
| Results card: kelp in year 5 and year 10          |                         |                                              |
| Results card: fish species and abalone in year 10 |                         |                                              |
| Passes all? If not, which fails?                  |                         |                                              |

4. Before you see the results card: describe your hybrid, show its cost, and explain which characteristic you took from each plan and why you predict it will pass C1 and C2.

**Answer:** Example: removal in years 1 and 2 plus the otter plan and the shellfish support step. Cost =  $2 \times 7 + 30 + 10 = 54$  points, within 60. Support 55 percent. From A we take speed (kelp regrows quickly while divers work); from C we take low cost and lasting urchin control; the support step meets K2. Prediction: kelp passes 25 percent by year 5 because the early clearing starts patches that otters then defend, and stays above 25 percent in year 10.

**Why:** Graded on a correct cost calculation and a prediction that is reasoned from the single-plan data, not on whether the prediction matches the card.

- Uses parts of at least two plans
- Cost calculated correctly and checked against K1
- Names the characteristic taken from each part
- Gives a reasoned prediction for C1 and C2

5. After reading the results card: did your hybrid perform as you predicted? Explain any difference.

**Answer:** Depends on the hybrid. Example for H3: as predicted, kelp reached 27 percent in year 5 and 44 percent in year 10, with 16 fish species, at 54 points and 55 percent support, so it passes all five; abalone fell to 4, which we had not thought about. Example for H1: kelp reached only 22 percent by year 5, so it failed C1, because sea stars take years to build up and two years of removal is not enough to bridge the gap.

**Why:** The student compares predicted with actual values and explains any gap with food-web or timing reasoning.

- Quotes the results-card values for their hybrid
- States whether each prediction held
- Explains a difference using the plans' characteristics

6. Final decision: which plan or hybrid does your group choose? Justify it with numbers for every criterion and constraint, compare it with at least one other option, state the trade-off you accept, and name the biggest uncertainty.

**Answer:** Example: we choose H3. It passes C1 (27 percent by year 5), C2 (44 percent in year 10), C3 (16 fish species), K1 (54 of 60 points) and K2 (55 percent support). H1 keeps far more abalone (13 versus 4) and has more support, but it misses C1 with 22 percent; H2 meets the criteria but costs 61. We accept that abalone will stay scarce where otters live, which hurts the abalone harvest, in exchange for a forest that can hold itself up after the divers stop. Biggest uncertainty: whether the otters stay in the cove.

**Why:** Either camp can earn full credit. A choice of H1 or H2 must say openly which agreed criterion or constraint it fails and argue why that is acceptable.

*Also acceptable: Choosing H1 to protect the abalone fishery and asking the partnership to accept a slower kelp target, or choosing H2 and asking for one more budget point, is acceptable when the failed test is named and the reason is argued with data.*

- Numbers for all five tests
- Comparison with at least one other option
- A clearly stated trade-off, including an ecosystem service
- A named uncertainty

## Hybrid results card (the teacher hands this out after your group commits to a design)

### Projected results for combined plans

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

| Hybrid                                          | Total cost (points) | Support | Kelp, year 5 (%) | Kelp, year 10 (%) | Fish species, year 10 | Red abalone per 100 m <sup>2</sup> , year 10 |
|-------------------------------------------------|---------------------|---------|------------------|-------------------|-----------------------|----------------------------------------------|
| H1. Removal years 1-2 + sea stars               | 54                  | 75%     | 22               | 30                | 15                    | 13                                           |
| H2. Removal years 1-3 + sea stars               | 61                  | 75%     | 27               | 32                | 15                    | 14                                           |
| H3. Removal years 1-2 + otters + support step   | 54                  | 55%     | 27               | 44                | 16                    | 4                                            |
| H4. Removal years 1-3 + otters + support step   | 61                  | 55%     | 33               | 46                | 16                    | 4                                            |
| H5. Removal years 1-2 + otters, no support step | 44                  | 40%     | 27               | 44                | 16                    | 4                                            |
| H6. Sea stars + otters + support step           | 80                  | 55%     | 16               | 34                | 15                    | 6                                            |
| H7. Removal every year, years 1-10              | 70                  | 80%     | 40               | 40                | 14                    | 15                                           |

Teaching dataset. In the otter hybrids, divers' early clearing lets kelp patches regrow; well-fed urchins at the patch edges then become otter food, so the otters keep the patches from being grazed after removal stops.

### Analysis questions: answer key

7. A group proposes urchin removal for years 1 to 3 plus the sea star plan. Compute its cost, say which constraint it breaks and by how much, and suggest one change that brings it within budget. What does your change cost in kelp at year 5?

**Answer:** Cost =  $3 \times 7 + 40 = 21 + 40 = 61$  points, which breaks K1 (at most 60) by **1 point**. One change: run removal for 2 years instead of 3 ( $2 \times 7 + 40 = 54$  points). That is H1 on the results card, and kelp in year 5 falls from 27 to 22 percent, so it then fails C1. Swapping the sea stars for otters plus the support step does not help at 3 removal years ( $21 + 30 + 10 = 61$ ); the otter version that fits the budget and meets the support constraint uses 2 removal years ( $14 + 30 + 10 = 54$  points, H3), which keeps year-5 kelp at 27 percent.

**Why:** Shows that trimming cost can push a plan below a criterion, which is why the constraint matters.

- Cost 61 calculated
- Identifies K1 and the 1-point overrun
- A change that brings the cost to 60 or less
- States the kelp consequence from the results card

8. Plan C alone does worst on kelp, yet otters are part of the strongest hybrid. Use the plan card (and clue 4 from Lab 2 if you did it) to explain why otters work better after divers have cleared some urchins.

**Answer:** In a barren, most urchins are thin and starved, and the plan card (and clue 4) says otters mostly skip them and hunt plump urchins near kelp. So otters alone in a bare cove find little worth eating and barely reduce the grazing, which is why kelp reaches only 6 percent by year 5. When divers first clear urchins, kelp patches regrow; urchins that move toward the kelp become well fed and worth catching, so the otters eat them and keep the patches from being grazed down after removal stops. Each plan supplies what the other lacks: removal starts the forest, otters defend it.

**Why:** Uses the prey-choice detail and food-web reasoning to explain why the combination works better than either part.

- Explains that otters prefer well-fed urchins near kelp
- Explains why otters alone barely change a barren
- Explains how removal plus otters keeps kelp after removal stops

9. Your chosen plan affects more than one ecosystem service. Use the fish and abalone data to describe one trade-off between ecosystem services, or between biodiversity and a fishery, in the plan you chose.

**Answer:** Example for H3: the forest returns (44 percent kelp, 16 fish species), which restores shelter for young fish and the dive and kayak visits, but red abalone stay scarce (4 per 100 m<sup>2</sup>, below the starting 6) because otters eat them, so the abalone harvest does not come back where the otters live. Example for H1: abalone recover to 13, supporting a future harvest, but the kelp comes back more slowly (22 percent at year 5).

**Why:** A trade-off names one benefit gained and one lost, with numbers.

- Names one service or value gained and one lost
- Uses at least one number from the data
- Matches the plan the student chose

10. Why is community support a real constraint rather than just an opinion? What could go wrong if a plan with 35 percent support went ahead anyway?

**Answer:** A plan needs permits, volunteers, funding and people's cooperation to work. With only 35 percent support, the plan could be blocked or delayed in the permit process, lose funding, or face opposition such as people harming otters or refusing to report problems, so it might never deliver its kelp results. Support is part of whether a plan is feasible, which is why it is a constraint.

**Why:** Social constraints affect whether a solution can be carried out and kept going.

- Explains that support affects whether the plan can happen or last
- Gives a plausible consequence of going ahead without support

11. Name the biggest uncertainty in your chosen plan and one measurement that would warn you early that the plan needs to change. Give the year and the value that would trigger a change.

**Answer:** Example for H3: biggest uncertainty, whether the otters stay in the cove. Early warning: if fewer than half of the released otters are still seen in the cove at the end of year 1, or if kelp is below 15 percent at the end of year 2, extend urchin removal and review the otter plan. Example for H1: if sunflower sea stars are found with wasting-disease sores in year 2, or urchins are above 20 per m<sup>2</sup> in year 3, add removal years.

**Why:** A good trigger is a specific measurement, a year and a value, tied to the plan's main uncertainty.

- Uncertainty tied to the chosen plan
- A measurable indicator
- A year and a trigger value

12. How is designing your hybrid like the way engineers developed the gecko-and-mussel adhesive described in the lesson?

**Answer:** The engineers tested a gecko-like pad (sticks dry, fails wet) and a mussel-like glue (sticks wet, hard to remove), found that neither met every criterion, and combined the best feature of each, then retested. We scored each plan against the criteria, found none passed everything, took the speed of urchin removal and the staying power and low cost of otters (or sea stars), combined them, and checked the result against the criteria again.

**Why:** Draws the parallel of test, compare, combine and retest.

- Describes the adhesive's test-and-combine process
- Matches each step to the lab

## Individual evidence of learning

Each student submits their own single-plan scorecard, kelp graph, hybrid design table and answers to q1 through q12. The scorecard and q2 show systematic evaluation against criteria and constraints; q3, q4 and q12 show combining the best characteristics of competing solutions; q6 and q9 are the evaluation of competing solutions for maintaining biodiversity and ecosystem services that the standard asks for; q11 shows planning for monitoring and revision.

## Assessment criteria

| Criterion                         | Proficient looks like                                                                                                                                                                           |
|-----------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Systematic evaluation</b>      | Every single plan marked pass or fail for all five tests, each with the deciding number, and all marks correct.                                                                                 |
| <b>Combining characteristics</b>  | The hybrid names the characteristic taken from each plan, cites the data showing it, and its cost is calculated correctly before the results card is read.                                      |
| <b>Evidence-based decision</b>    | q6 cites numbers for C1, C2, C3, K1 and K2, compares the choice with at least one alternative, and states the trade-off accepted, including the effect on abalone or another ecosystem service. |
| <b>Scientific reasoning</b>       | q8 explains with food-web reasoning why otters do better after urchin removal; q7 is calculated correctly.                                                                                      |
| <b>Uncertainty and monitoring</b> | Names a specific uncertainty and a measurable trigger with a year and value (q11).                                                                                                              |

## Accessibility adaptations

- Provide the scorecard with plan A completed as a model, and a cost card listing the cost of removal for 1, 2, 3, 5 and 10 years.
- Allow the kelp graph to be drawn on a pre-printed grid with the 25 percent line already in place, or replaced by highlighting values of 25 or more in the table.
- Offer sentence frames for q6: 'We chose \_\_\_ because it passes \_\_\_ with \_\_\_. We accept \_\_\_ because \_\_\_. The biggest uncertainty is \_\_\_.'

- Let a student present the decision by recording a short audio or video, and allow the final justification to be dictated to a partner.

## Low-cost alternative

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No materials beyond printing are needed. If printing is limited, project the plan cards and datasets, have students draw the scorecard in their notebooks, and read out the results-card row for each group's hybrid when it is committed.

## Model limitations

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Driftwood Cove, the costs, the community survey and every projection are invented for teaching. The projections are written to follow patterns reported by researchers: removing urchins can regrow kelp quickly, but urchins return when removal stops; sea otters in Monterey Bay mostly ate well-fed urchins near remaining kelp and helped forest patches resist overgrazing rather than clearing barrens; raising sunflower sea stars in captivity for release is still at an early research stage. Real outcomes would also depend on storms, water temperature, how many urchin larvae arrive, disease and where otters choose to go. Real decisions would involve federal and state permits (sea otters are protected under the Endangered Species Act and the Marine Mammal Protection Act), consultation with tribes and public review. Use the lab to practice evaluating solutions, not to predict any real coast.

## Teacher notes

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Single-plan marks: A passes C1 (40), fails C2 (12) and C3 (10), passes K1 (35) and K2 (80). B fails C1 (15), passes C2 (28), C3 (14), K1 (40) and K2 (70). C fails C1 (6), C2 (20), C3 (12) and K2 (35), passes K1 (30); C plus the support step costs 40 and reaches 55 percent support but still fails C1, C2 and C3. Results card: H1 54 points, 75 percent, kelp 22 and 30, fish 15, abalone 13 (fails C1). H2 61 points (fails K1 by 1). H3 54 points, 55 percent, kelp 27 and 44, fish 16, abalone 4 (passes all). H4 61 points (fails K1). H5 44 points but 40 percent support (fails K2). H6 80 points, 55 percent, kelp 16 at year 5 (fails C1 and K1). H7 70 points (fails K1). If a group designs a hybrid not on the card, give them the closest row and ask how their version would differ. Grade the decision (q6) on the quality of the evidence and the honesty about trade-offs, not on which hybrid is chosen.