

Case File: Two Kelp Coves, One Heat Wave

Investigation question: Two fictional kelp coves on the California coast went through the same sea star die-off and the same marine heat wave. Why did one keep its forest and most of its species while the other became an urchin barren?

Evidence-based mystery

Groups of 4

1 session

Setup 5 · Activity 50 · Cleanup 5 min

MS-LS2-4 · practice

MS-LS2-5 · supports

Scientific purpose

Students act as a survey team handed six years of dive data from two fictional coves. They compare the coves' species richness and key populations, test five competing explanations (the 'suspects') against eight clue cards, and build a causal chain that explains why only one kelp forest collapsed. The case is patterned on what happened on California's north and central coasts after 2013, so students meet keystone species, multiple stressors and the power of a comparison site in one investigation.

Why this helps students with this chapter

The textbook tells the otter story as one cause with a happy ending. Working a realistic case shows students that ecosystems often change because of several stressors at once, that the most useful evidence is a comparison between two places that shared most conditions, and that timing can rule a suspect out. It also exposes a trade-off they will need in Lab 3: the cove with sea otters has far fewer abalone.

Standards connections

MS-LS2-4 (practice, constructing an argument from evidence that changes to physical and biological components affect populations): Students argue from survey data and clue cards that a warmer ocean (physical) and the loss of urchin predators (biological) changed urchin, kelp, abalone and community-wide species numbers, and they rule competing explanations in or out. The data are simulated, so this builds the Grade 7 argument practice rather than assessing the PE with empirical evidence.

MS-LS2-5 (supports, diagnosing why biodiversity and ecosystem services were lost before evaluating solutions): Knowing which change caused the collapse is the first step in choosing a fix; q8 asks which change would most likely have protected the cove. Lab 3 continues at Driftwood Cove and evaluates competing restoration plans.

Roles (rotate each session)

- **Case lead:** Runs the suspect table, keeps the group on one suspect at a time, and makes sure every verdict has a written reason.
- **Data analyst:** Computes richness totals, percent change and urchin increase, and reads numbers from the datasets when the group needs them.
- **Clue reader:** Reads each clue card aloud and asks the group whether it supports, rules out or says nothing about each suspect.

- **Chain builder:** Draws the causal chain for Driftwood Cove and checks that every arrow is backed by data or a clue.

Materials

Item	Quantity	Per	Note
Case file (the recording sheet with both coves' datasets and the suspect table)	1	student	
Clue cards 1 to 8, printed and cut, in two envelopes (Round 1: cards 1-4; Round 2: cards 5-8)	1 set	group	
Highlighters in two colors	2	group	
Calculator	1	group	
Chart paper and markers for a poster-size causal chain (optional)	1 sheet	group	
Projected photos of a kelp forest, an urchin barren and a sunflower sea star	1 set	class	

Estimated cost: 2 to 5 per class (an estimate; Estimate for printing a case file per student and one set of clue cards per group. Envelopes, highlighters and chart paper are usually classroom stock.)

Safety

- Paper-based activity with no physical hazards; if students cut their own cards, use classroom scissors at their desks.
- Keep the case clearly fictional: the coves and every number are invented teaching data, so students should not quote them as facts about real California places.

Teacher preparation and setup

1. Print a case file for every student and one set of clue cards per group; cut the cards and put cards 1-4 in an envelope marked Round 1 and cards 5-8 in one marked Round 2.
2. Read the suspect verdicts in the answer key. Decide when to reveal the real events behind the case; the debrief is recommended, so groups reason from the evidence rather than from what they have heard.
3. Find and project photos of a healthy kelp forest, an urchin barren and a sunflower sea star from a public source such as NOAA or a California aquarium.
4. Write the rule of evidence on the board: a suspect is 'needed' only if it helps explain why the two coves ended differently, or when the change happened.

Investigation design

Independent variable The cove: Lupine Cove (sea otters present) and Driftwood Cove (no sea otters). Both coves shared the heat wave and the sea star die-off.

Dependent variable Kelp canopy, purple urchin density, sunflower sea star density, red abalone density, and species richness of fish, invertebrates and seaweeds in the survey years 2012, 2014, 2016 and 2018.

Controlled	Same survey method and transect area at both coves; Same survey years; Same water temperature changes and sea star die-off at both coves; Same clue cards for every group
Trials	One case file per group; the class compares verdicts and causal chains across groups in the debrief.
Comparison	Lupine Cove is the comparison site: anything that happened at both coves cannot, by itself, explain what happened at only one.

Student procedure

1. Read the case introduction and both cove datasets. In q1, write your first hunch about the biggest difference between the coves by 2018.
2. Data analyst totals the species for each cove and year in the totals table and computes the percent change from 2012 to 2018 for each cove (q2). The others check the arithmetic.
3. Data analyst computes how many times purple urchin density grew at each cove from 2012 to its highest survey value (q3). Highlight in one color every change that happened at both coves and in the other color every change that happened at only one.
4. Open Round 1 (clue cards 1-4). The Clue reader reads each card aloud; the group decides which suspects it supports and which it rules out or weakens, and records the card number in the suspect table.
5. Open Round 2 (cards 5-8) and repeat. Rule a suspect out if its timing is wrong or if it cannot explain why only one cove collapsed.
6. Give every suspect a verdict: needed to explain the difference, contributed but cannot explain the difference, or ruled out. Each verdict needs one written reason.
7. Chain builder draws the causal chain for Driftwood Cove from the first stressors to the loss of species, labeling each arrow with its evidence, and adds a box showing what was different at Lupine Cove.
8. Answer q4 as a group. Then answer the analysis questions individually.

Expected observations

- Total species: Lupine 58, 56, 50, 53 (change –8.6 percent); Driftwood 57, 53, 31, 24 (change –57.9 percent).
- Purple urchins grew about 48 times at Driftwood Cove (1.0 to 48 per m²) but only 3 times at Lupine Cove at their peak (2.0 to 6.0), and fell again there by 2018.
- Both coves lost their sunflower sea stars and had the same warm water; only the presence of sea otters differs.
- Groups rule out S4 (harvest steady while the forest was healthy; abalone declined after the kelp) and S5 (no change in the creek, which reaches both coves), and judge S1 and S2 as contributing but not explaining the difference.

Likely difficulties

- Treating every suspect as guilty because each 'did something'. Push the rule of evidence: what explains the difference between coves?
- Reading the abalone decline as a cause rather than an effect. Ask which came first in the data, the kelp loss or the abalone loss, and what abalone eat.
- Percent change errors: dividing by the 2018 value instead of the 2012 value, or reporting the difference in species instead of the percent.
- Concluding from Lupine's low abalone that otters are harmful. Use q6 to separate 'bad for abalone harvests' from 'bad for the ecosystem'.

Structured debrief

1. Collect each group's verdicts on the board. Most groups agree that S4 and S5 are ruled out and that S3 is needed; the debate is usually whether S1 and S2 'count'. Settle it with the rule of evidence: both stressors hit both coves, so they set the stage, but only the missing otters explain why the stage collapsed at one cove. Ecologists call this multiple stressors.
2. Reveal the real events. North of San Francisco, where there are no sea otters, sea star wasting disease from 2013 and a marine heat wave from 2014 to 2016 were followed by an explosion of purple urchins and the loss of more than 90 percent of the bull kelp canopy along more than 350 km of coast. Red abalone starved, and the recreational fishery closed in 2018; in December 2025 the closure was extended to 2036. On the central coast, researchers in Monterey Bay found that sea otters ate many more urchins after the boom, mostly plump urchins near remaining kelp, which helped those forest patches hold on.
3. Point out what the fenced plot (clue 8) added: it was a small experiment. Kelp grew in warm water when urchins were kept out, so warmth alone did not stop kelp. Ask what other experiment would strengthen the case.
4. Raise the abalone trade-off (q6) and carry it into Lab 3: bringing otters back could help kelp, but otters eat abalone, crabs and urchins that people harvest. Which criteria would a fair plan need?

Recording sheet: what students fill in

Lab 2 case file: Two Kelp Coves, One Heat Wave

Lupine Cove and Driftwood Cove are **fictional** rocky coves on the California coast, and every number in this file is a **teaching dataset** patterned on real events. Divers surveyed the same underwater transects at both coves every two years from 2012. By 2018, Driftwood Cove's kelp forest was nearly gone and the rock was carpeted with purple sea urchins, a habitat called an **urchin barren**. Lupine Cove still had a forest. Your team must work out why, using the data and the clue cards.

Lupine Cove survey data

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

Year	Kelp canopy (% of area)	Purple urchins per m ²	Sunflower sea stars per 100 m ²	Sea otters seen per km of shore	Red abalone per 100 m ²	Summer water above normal (°C)
2012	55	2.0	3.0	6	3	0.0
2014	50	2.5	0.5	6	3	1.0
2016	34	6.0	0	7	2	2.5
2018	46	3.5	0	7	2	0.5

Teaching dataset for a fictional cove. Kelp canopy is the share of the survey area covered by kelp at the surface.

Driftwood Cove survey data

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

Year	Kelp canopy (% of area)	Purple urchins per m ²	Sunflower sea stars per 100 m ²	Sea otters seen per km of shore	Red abalone per 100 m ²	Summer water above normal (°C)
2012	60	1.0	3.5	0	40	0.0
2014	52	1.5	0.5	0	38	1.0
2016	6	32	0	0	20	2.5
2018	3	48	0	0	7	0.5

Teaching dataset for a fictional cove, surveyed with the same method as Lupine Cove.

Species richness on the survey transects

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

Cove and year	Fish species	Invertebrate species (not counting urchins)	Seaweed species (including kelp)
Lupine 2012	18	26	14
Lupine 2014	18	25	13
Lupine 2016	16	23	11
Lupine 2018	17	24	12
Driftwood 2012	17	25	15
Driftwood 2014	16	24	13
Driftwood 2016	10	15	6
Driftwood 2018	8	12	4

Number of different species recorded on the same transects in each survey (teaching dataset).

Total species and change

Cove	2012 total	2014 total	2016 total	2018 total	Change 2012 to 2018 (%)
Lupine Cove					
Driftwood Cove					

1. First hunch: from the two cove datasets alone, what is the biggest difference between the coves by 2018, and what do you think caused it?

Answer: Hunches vary. The biggest difference by 2018 is that Driftwood Cove's kelp fell from 60 to 3 percent while its urchins rose from 10 to 48 per m², whereas Lupine Cove kept 46 percent kelp. A strong hunch links the urchin explosion to the kelp loss and notices that only Lupine Cove has sea otters.

Why: This is a first hunch, graded on whether it names a real difference from the data and offers a testable cause.

- Names a difference with numbers
- Proposes a cause that can be tested against the clues

2. Compute the percent change in total species from 2012 to 2018 for each cove. Show the calculation.

Answer: Lupine: total 2012 = $18 + 26 + 14 = 58$; total 2018 = $17 + 24 + 12 = 53$; change = $(53 - 58) \div 58 \times 100 = -8.6$ percent. Driftwood: total 2012 = $17 + 25 + 15 = 57$; total 2018 = $8 + 12 + 4 = 24$; change = $(24 - 57) \div 57 \times 100 = -57.9$ percent. (Other totals: Lupine 2014 = 56, 2016 = 50; Driftwood 2014 = 53, 2016 = 31.)

Why: Percent change is the difference divided by the starting value. Driftwood lost more than half its species; Lupine lost under a tenth.

Also acceptable: -8.62 and -57.89 percent, or 'about 9 percent lower' and 'about 58 percent lower', earn full credit.

- Correct totals
- Divides by the 2012 value
- About -9 percent and about -58 percent

3. How many times larger was the purple urchin density at its highest survey value than in 2012, at each cove? Show the calculation.

Answer: Driftwood: highest value 48 (2018) $\div 1.0$ (2012) = **48 times**. Lupine: highest value 6.0 (2016) $\div 2.0$ (2012) = **3 times**, and it fell back to 3.5 by 2018.

Why: Both coves saw some urchin increase after the sea stars died, but only Driftwood's became an explosion.

- Uses each cove's highest survey value and its 2012 value
- 48 times and 3 times

Clue cards (Round 1: cards 1-4; Round 2: cards 5-8)

1 Clue 1. Water temperature log

Summer water at both coves ran 1 to 2.5°C above normal from 2014 to 2016. Warm surface water along this coast carries fewer nutrients, and divers at both coves reported thinner, shorter kelp in the hottest summer.

2 Clue 2. Sea star die-off

A wasting disease spread along the Pacific coast starting in 2013. Sunflower sea stars at both coves developed sores and fell apart; after 2015 none were seen at either cove. Sunflower sea stars are fast-moving predators that eat purple urchins.

3 Clue 3. Diver's notebook, Driftwood Cove, 2015

The purple urchins have left their cracks. They are crawling across open rock in dense fronts, chewing through kelp stalks near the bottom so whole plants break loose and drift away. Behind the front there is only bare rock and urchins.

4 Clue 4. Otter watch, Lupine Cove

Volunteers recorded what sea otters brought up from their dives. In 2012 about 1 in 10 prey items was a purple urchin; in 2016 about 4 in 10 were. Most were plump urchins taken at the edges of the remaining kelp; otters mostly ignored the thin, starved urchins on bare rock. (Teaching data.)

5 Clue 5. Abalone condition report, 2017

Many red abalone at Driftwood Cove had shrunken bodies and were losing their grip on the rock, and empty shells were common. Abalone feed mainly on drifting pieces of kelp. At Lupine Cove the few abalone found were tucked deep in cracks and looked well fed.

6 Clue 6. Harvest records

Recreational divers took about the same number of red abalone from Driftwood Cove each year from 2008 to 2017, including the years when the forest was healthy; none were taken in 2018 after the fishery closed. No one harvests abalone at Lupine Cove, where they are scarce and hidden in cracks.

7 Clue 7. Creek water tests

A small creek enters the sea between the two coves. Monthly tests from 2012 to 2018 showed no change in mud, nutrients or chemical pollutants, and the creek's plume reaches both coves about equally.

8 Clue 8. Young kelp and a fenced plot

Each spring, young kelp appeared on the rock at both coves. At Lupine Cove many grew into adult kelp by late summer. At Driftwood Cove, young kelp vanished within weeks wherever urchins were present, but grew tall inside a small mesh-fenced test plot that kept urchins out, even in the warm year of 2016.

Suspect table

Suspect	Clues and data that support it	Clues and data that rule it out or weaken it	Verdict (needed / contributed / ruled out)
S1. The heat wave killed the kelp.			
S2. The sea star die-off let the urchins take over.			
S3. Driftwood Cove had no sea otters to eat urchins.			
S4. Abalone divers overharvested and damaged the forest.			
S5. Pollution from the creek.			

-  Causal chain for Driftwood Cove: start with the stressors and end with the loss of species. Write the evidence (a data value or clue number) on every arrow. Add a box showing what was different at Lupine Cove and where it breaks the chain.

Answer: Chain: heat wave (clue 1, +2.5 °C) and sea star die-off (clue 2, 3.5 to 0 per 100 m²) → urchins no longer controlled → urchins multiply and leave cracks (1.0 to 48 per m², clue 3) → kelp grazed away (60 to 3 percent, clue 8) → kelp-dependent species lost (57 to 24 species) and abalone starve (40 to 7 per 100 m², clue 5). Lupine box: sea otters eat more urchins (clue 4), breaking the chain at the 'urchins multiply' step.

Why: The chain must run in cause-and-effect order, with evidence on each arrow, and show where otters interrupt it.

- Both stressors at the start
- Urchin increase before kelp loss before species loss
- Evidence on every arrow
- Otter box placed at the urchin step

4. Group explanation: which suspects were needed to explain the collapse, and why did only Driftwood Cove become an urchin barren? Use at least three numbers or clues.

Answer: The heat wave (clue 1) weakened kelp at both coves, and the sea star die-off (clue 2) removed an urchin predator at both coves, so neither alone can explain why only one cove collapsed. The difference is sea otters: at Lupine Cove otters switched to eating many more urchins (1 in 10 prey items in 2012 to 4 in 10 in 2016, clue 4), urchins peaked at only 6 per m² and kelp recovered to 46 percent. At Driftwood Cove, with no otters and no sea stars, urchins rose 48 times, left their cracks and grazed the kelp to 3 percent (clue 3); young kelp survived only where urchins were fenced out (clue 8). Species that rely on kelp disappeared (total species fell 58 percent) and abalone starved (clue 5). Harvest (clue 6) and the creek (clue 7) are ruled out.

Why: A full answer treats S1 and S2 as contributing stressors shared by both coves and S3 as the needed difference, and supports each step with data or clues.

- Identifies the missing otters as the difference between coves
- Treats heat wave and sea star loss as shared, contributing stressors
- Uses at least three numbers or clues
- Rules out harvest and pollution

Analysis questions: answer key

5. Why is Lupine Cove so useful to this investigation? Explain how having a comparison site let you rule suspects in or out.

Answer: Lupine Cove went through the same heat wave and the same sea star die-off, so anything the two coves shared cannot by itself explain why only Driftwood collapsed. That let us demote S1 and S2 to contributing causes, rule out the creek (it reaches both coves), and focus on what differed: the otters.

Why: A comparison site works like a control: it shows what happens when most conditions are the same.

- Says the coves shared most conditions
- Explains how shared conditions cannot explain a difference
- Gives an example of a suspect demoted or ruled out

6. Lupine Cove had far fewer red abalone than Driftwood Cove even in 2012. Use the clue cards to explain why. Does this mean sea otters are bad for the kelp forest ecosystem? Explain.

Answer: Sea otters eat abalone as well as urchins, so at Lupine Cove abalone survive mainly deep in cracks where otters cannot reach them (clues 5 and 6), which keeps their numbers low. That is a cost to people who want to harvest abalone, but it does not make otters bad for the ecosystem: by keeping urchins in check they kept the whole kelp forest and almost all of its species (53 of 58), while Driftwood's large abalone population starved anyway when its kelp disappeared (40 down to 7).

Why: Separates a cost to one harvested species from the health of the whole community; uses the data to show the forest is what feeds abalone in the first place.

- Explains that otters eat abalone
- Distinguishes a harvest trade-off from ecosystem health
- Uses data comparing the coves

7. Sea otters are far less numerous than urchins at Lupine Cove. Use the data to explain why the otter still counts as a keystone species.

Answer: Only about 6 or 7 otters were seen per kilometer of shore, while a forest strip 1 km long and 100 m wide at 2 urchins per m² holds about 200,000 urchins. Yet the otters' urchin eating kept urchins at 2 to 6 per m² and the forest standing (46 percent kelp, 53 species), while the otter-free cove lost its forest. An effect that large from so few animals is what makes a keystone species.

Why: The keystone idea is an effect out of proportion to abundance.

- Compares otter numbers with urchin numbers
- Describes the large effect on kelp or species
- Links the two as the keystone definition

8. Which single condition would most likely have protected Driftwood Cove's forest, and what is your strongest piece of evidence? Give one reason your answer could still be wrong.

Answer: Having sea otters (or another urchin predator still present) would most likely have protected the forest. Strongest evidence: Lupine Cove had the same heat and the same sea star loss but kept its kelp, and its otters were seen eating many more urchins (clue 4); the fenced plot (clue 8) shows kelp could grow in the warm water once urchins were kept away. It could still be wrong because the coves may differ in other ways the file does not show, such as depth, waves or how many urchin larvae arrived, and there is only one comparison site.

Why: A strong answer picks a condition the evidence supports and honestly names the limits of a two-site comparison.

Also acceptable: Arguing that sunflower sea stars surviving would have protected the forest earns credit if it uses the evidence that urchins stayed low while sea stars were present in 2012 and 2014.

- Names a condition supported by the evidence
- Cites the strongest specific evidence
- Gives a genuine reason for doubt

9. Use the richness table to explain how the kelp collapse spread from a few species to the whole community, and why kelp-forest biodiversity is a useful measure of the cove's health.

Answer: Kelp is the habitat and food for many species. When urchins grazed the kelp away at Driftwood Cove, seaweed species fell from 15 to 4, and animals that live in or feed on kelp followed: fish from 17 to 8 and other invertebrates from 25 to 12. Lupine Cove, which kept its kelp, lost only a few species. Because so many species depend on the forest, the share of the cove's natural species still present is a good sign of whether the whole ecosystem is working.

Why: Connects one population change to community-wide loss and to the idea that the completeness of an ecosystem's biodiversity measures its health.

- Uses the richness numbers for at least two groups
- Explains kelp as habitat and food
- Links completeness of species to ecosystem health

10. This case is fictional but patterned on real events. What can a case like this teach you, and what can it not prove?

Answer: It can teach how to compare sites, test competing explanations against evidence, and reason about keystone species and multiple stressors, using a pattern that really happened in California. It cannot prove what caused any real kelp collapse, because the numbers are invented, there are only two sites, and real coves differ in many more ways.

Why: Students should separate learning a method from proving a real-world claim.

- Names something the case can teach
- Names a limit tied to simulated data or the two-site design

Individual evidence of learning

Each student submits their own completed totals table, suspect table, causal-chain drawing and answers to q1 through q10. The suspect table and q4 are the argument from evidence; q5 and q10 show reasoning about what the evidence can and cannot support; q6 and q7 show understanding of keystone effects and trade-offs.

Assessment criteria

Criterion	Proficient looks like
Data analysis	Totals, percent changes (about –9 and –58 percent) and urchin increases (3 times and 48 times) correct, with calculations shown.
Evaluating competing explanations	Every suspect has a verdict backed by a specific clue or data value; S4 and S5 ruled out with timing or comparison evidence; S3 identified as the difference.
Causal model	The causal chain runs from heat wave and sea star loss through urchin increase and kelp loss to species loss, every arrow labeled with evidence, with Lupine's otters shown breaking the chain.
Keystone and trade-off reasoning	Explains the otter's large effect relative to its numbers (q7) and separates the abalone harvest trade-off from ecosystem health (q6).

Accessibility adaptations

- Provide a version of the datasets with the two coves side by side in one table and the 'both coves' changes already highlighted.
- Read clue cards aloud for the whole class in each round, and offer cards with key words in bold and a picture icon for each organism.
- Give the suspect table with sentence starters: 'Clue __ supports this because...' and 'Clue __ rules this out because...'.
- Allow the causal chain to be built from pre-printed boxes and arrows that students arrange and glue, or as a spoken explanation recorded on a device.

Low-cost alternative

No materials beyond printing are needed. If printing is limited, project the datasets and read the clue cards aloud one at a time, with students keeping the suspect table in their notebooks.

Model limitations

Lupine Cove and Driftwood Cove are fictional and every number is a simulated teaching dataset, written so that the evidence points to one key difference. Real coves differ in many more ways (depth, wave exposure, rock type, fishing, distance from the otter range), real surveys have measurement error, and real investigations rarely have such a tidy comparison site. The case simplifies the science: otters are one of several urchin predators, kelp responds to nutrients and storms as well as grazing, and researchers still debate how quickly barrens can recover. A two-site comparison shows a pattern consistent with a cause; it cannot prove the cause the way a replicated experiment could.

Teacher notes

Verdicts: S1 heat wave, contributed (thinned kelp at both coves, clue 1) but cannot explain the difference, and kelp grew inside the urchin-proof plot in the warm year (clue 8). S2 sea star die-off, contributed (removed a predator at both coves, clue 2) but shared by both. S3 no otters, needed: the one difference between the coves, with otters eating far more urchins at Lupine (clue 4) and urchins exploding only at Driftwood. S4 abalone harvest, ruled out: harvest was steady while the forest was healthy (clue 6), and the abalone decline followed the kelp loss and came from starvation (clue 5). S5 creek pollution, ruled out: no change in the water, and it reaches both coves (clue 7). Accept 'S1 and S2 were needed too' if the student explains that the collapse needed the shared stressors plus the missing otters; the key distinction is between causes shared by both coves and the cause that explains the difference.