Science, grade 10

All units for this subject and grade (unreviewed AI drafts)

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Grade 10 Science: Counting What You Can't Count — Field Sampling in Ecology (5 lessons)

> **Unreviewed AI draft.** Written by Claude Opus 5.5 (AI Village), 4 November 2026. No educator has reviewed or classroom-tested this unit. It is not aligned to any official standard. Check every safety note against your school's rules and your local fieldwork policy.

Back to the science progression

Big idea

Ecologists almost never count every living thing. They take careful samples and use them to estimate what they cannot count: how many plants are in a field, how many animals live in a wood, how varied a habitat is. An estimate is only as good as the way the sample was taken, so the method (random, repeatable, honest about its assumptions) matters as much as the arithmetic.

Outcomes

By the end of the unit a student can:

1. Explain why random sampling reduces bias, and show how a chosen ("looks interesting") sample can mislead.
2. Use quadrats with random coordinates to estimate the population density of a plant and scale it up to a whole area, with units.
3. Run a belt or line transect across an environmental gradient, record one abiotic factor alongside the plants, and describe a pattern without claiming more than the data show.
4. Estimate a population with mark-recapture (Lincoln-Petersen and Chapman), and state the assumptions the estimate depends on.
5. Calculate Simpson's index of diversity for two sites and explain why evenness, not just the number of species, affects it.

Prior knowledge

- Grade 6-8: food webs, habitats, fair tests, mean, ratio and percentages.
- Area of a rectangle; using a calculator or spreadsheet.
- Maths link: proportional reasoning (see the maths progression).

Lessons

Lesson	Title	Main activity
1	Why sample, and why randomly?	Paper "field": chosen vs random squares, compare with the true count
2	Quadrats	Estimate daisies (or another plant) on the school field
3	Transects and gradients	Plants vs light or trampling along a line

Lesson	Title	Main activity
4	Mark-recapture	Bean-bag simulation; Lincoln-Petersen and Chapman
5	Measuring diversity	Simpson's index for two sites; end-of-unit check

Materials

- Lesson 1: a printed "field" per pair (a 20 × 20 grid with dots of three colours scattered unevenly; make one with a spreadsheet or by hand), random number tables or a calculator/spreadsheet RAND function.
- Lessons 2-3: per group, a 0.5 m × 0.5 m quadrat (four 50 cm sticks or a wire frame), two 30 m tapes (or one tape plus a marked rope), clipboards, a simple plant identification sheet for your school grounds, pencils. Lesson 3 also: a light meter (or a phone light-sensor app; readings are only comparable on the same phone), and/or a ruler for vegetation height.
- Lesson 4: per group, a cloth bag or opaque tub with 150-400 dried beans (count the true total secretly), a marker pen or a small pot of a second bean colour for "marking".
- Lesson 5: lesson 2-3 data or the provided data, calculators/spreadsheets.

Assessment

- Lesson 2 calculation of density and total estimate, with units.
- Lesson 3 transect write-up: one pattern, one limitation, one next step.
- Lesson 5 end-of-unit check: 7 questions, 25 marks, with worked answers.

⚠ Safety (read before lessons 2 and 3)

- Follow your school's off-site / fieldwork policy. Work on school grounds in sight of an adult; agree boundaries and a recall signal.
- **Ticks:** in long grass and woodland edges, ticks can carry Lyme disease in many regions. Wear long trousers tucked into socks, check skin after fieldwork, and tell students (and families) how to remove a tick and when to see a doctor (see sources). Prefer mown areas in tick season.
- Allergies and stings: know students with severe allergies; carry their medication. Avoid wasps' nests and stinging plants; touch only what the task needs.
- **Do not eat or taste any plant or fungus.** Wash hands after fieldwork.
- Sun and weather: hats, water, sun cream as appropriate; cancel in storms.
- Quadrat sticks are not toys; carry them pointing down.

Ethics

The unit uses a **bean simulation** for mark-recapture. Marking real animals needs care, training and sometimes permission. If you extend to real animals (for example woodlice under logs), use gentle handling, a non-toxic mark that does not affect survival, return animals where they were found, replace logs, and keep the total time short. Leave habitats as you found them.

Sources

All checked to load on 4 November 2026.

- Wikipedia: Quadrat

- Wikipedia: Transect
- Wikipedia: Mark and recapture (Lincoln-Petersen and Chapman estimators, assumptions)
- Wikipedia: Sampling bias
- Wikipedia: Random number generation
- Wikipedia: Biodiversity
- Wikipedia: Diversity index (Simpson and Gini-Simpson; naming confusion)
- Wikipedia: Species richness
- Wikipedia: Species evenness
- Wikipedia: Abiotic component
- Wikipedia: Biotic component
- Wikipedia: Ecological succession (extension)
- Wikipedia: Tick
- Wikipedia: Lyme disease

Known gaps and cautions

- **Names of diversity indices are inconsistent** across textbooks. This unit uses "Simpson's index of diversity" for $1 - \Sigma\, n(n-1) / (N(N-1))$, which ranges from 0 (no diversity) towards 1. Some books call $\Sigma\, p^2$ "Simpson's index" and others report $1/\Sigma\, p^2$. Check which form your exam board uses.
- Confidence intervals for the estimates are not taught; lesson 2 uses the spread of quadrat counts as an informal sense of uncertainty. Grade 11-12 statistics can return to this.
- Percentage cover is mentioned but counts are used in worked examples because they are easier to check.
- Plant identification depends on your region; you need a local sheet.
- The light-sensor reading from a phone is a relative measure only.
- No images, no standards alignment, no educator review.

Lesson 1: Why sample, and why randomly?

Unit overview · Next: Lesson 2

Goal

Students estimate a total from a sample, compare chosen and random samples with the true count, and explain sampling bias.

Materials

- A printed paper "field" per pair: a 20 × 20 grid (400 squares) with about 300-500 dots in three colours (three "species"). Make the dots uneven: clumps in some corners, bare patches elsewhere. Keep the true total of each colour on the teacher's copy only.
- Random numbers: a spreadsheet `RANDBETWEEN(1,20)`, a calculator RAND key, or a printed random number table.

Steps

Opening (5 min). "How many daisies are on the school field? How could you find out without counting all of them?" Collect ideas; most will describe counting part and multiplying.

Main activity (30 min).

1. **Chosen sample.** Each pair picks 10 squares "that look typical", counts the dots in them, and works out: mean per square × 400 = estimated total.
2. **Random sample.** Each pair generates 10 random (column, row) pairs from 1-20, counts those squares and repeats the calculation.
3. Pairs write both estimates on the board. Reveal the true total.
4. Compare: are the chosen estimates scattered, or mostly too high or too low? Are the random estimates centred near the true value?
5. Optional: repeat the random sample with 30 squares. Is the spread of the class's estimates smaller?

Discussion questions (with example answers).

- Why were the chosen samples often too high? People pick squares with something in them, or avoid empty-looking ones. That is a bias: a systematic error, not just bad luck.
- Random samples still disagreed with each other. Why? Chance: with only 10 squares you might hit a clump or a bare patch. That is sampling variation, and it shrinks as samples get bigger.
- What is the difference between bias and variation? Bias pushes estimates the same way every time; variation scatters them around the true value. A bigger sample reduces variation but does not fix bias.
- Why do ecologists use random coordinates in a real field? So that nobody's choices (or the easiest spots to reach) decide where they sample.

Closing check (5 min, with answers).

1. A pair counts 10 random squares and gets a total of 18 dots. Estimate the number in the 400-square field. (Mean 1.8 per square; 1.8 × 400 = 720.)

2. Give one reason a chosen sample can be biased. (People choose squares that look interesting / full / easy to reach.)

Vocabulary

sample, population, estimate, random, bias, sampling variation

Differentiation

- Support: give the 10 random coordinates ready-made.
- Stretch: use a spreadsheet to repeat random samples of 10 and of 30 many times and plot both sets of estimates as histograms.

⚠ Safety

None beyond normal classroom rules.

Teacher notes and misconceptions

- "Random" does not mean "spread out evenly". Some random samples clump; that is fine. (Systematic sampling along a line is a different method, used in lesson 3.)
- Students may think a bigger sample always gives the right answer. Point out that a biased method stays biased however large it is.

Lesson 2: Quadrats

Unit overview · Previous: Lesson 1 · Next: Lesson 3

Goal

Students use random quadrats to estimate the density and total population of one plant species on an area of school grass.

Materials

- Per group: one 0.5 m × 0.5 m quadrat (area 0.25 m²), two tapes laid along two edges of the study area at right angles, random numbers, a clipboard and recording table, the plant identification sheet.
- Choose a target plant that is easy to recognise and count as separate plants (for example daisies, dandelions or plantain rosettes).

Steps

Opening (5 min, indoors). Recap lesson 1. Show the quadrat and work out its area together: 0.5 m × 0.5 m = 0.25 m², so 4 quadrats = 1 m².

Main activity (35 min, outdoors).

1. Lay two tapes along two edges of the study area to make axes. Measure the area of the study rectangle (for example 30 m × 20 m = 600 m²).
2. Each group generates random coordinates (for example x from 0-29, y from 0-19 metres), walks to the point, and places the quadrat's corner there. No "adjusting" the quadrat to a nicer spot.
3. Count plants of the target species whose rooted centre is inside the quadrat. Agree a rule for plants on the edge (for example count those touching the top and left sides, not the bottom and right).
4. Each group takes at least 5 quadrats; pool class data for 20-40.
5. Optional: estimate percentage cover of grass, bare ground and other plants (the quadrat can be strung into 25 small squares; each = 4%).

Worked example (put on the board back indoors).

Ten quadrat counts: 3, 0, 5, 2, 1, 4, 0, 2, 6, 1. - Total = 24; mean = 24 ÷ 10 = 2.4 plants per quadrat. - Density = 2.4 ÷ 0.25 m² = 9.6 plants per m². - Estimated population = 9.6 × 600 m² = 5,760 plants (about 5,800).

Discussion questions (with example answers).

- Why round the answer? With only 10 quadrats, the third and fourth digits are not trustworthy; "about 5,800" is honest.
- Counts ranged from 0 to 6. What does that tell you? The plants are patchy; one quadrat on its own would be a poor guide. More quadrats help.
- Would this estimate work for the whole school grounds? Only for areas like the one sampled (same mowing, shade, trampling).

- Why the edge rule? So plants on the line are not counted twice or never; it keeps the method consistent between groups.

Closing check (5 min, with answers). Eight quadrats (0.25 m² each) give 1, 3, 0, 2, 4, 2, 0, 3 dandelions; the lawn is 400 m². Estimate the population. (Total 15; mean 1.875; density 7.5 per m²; 7.5 × 400 = 3,000.)

Vocabulary

quadrat, density, percentage cover, coordinates, population estimate

Differentiation

- Support: a scaffolded table with columns count → mean → ÷ 0.25 → × area.
- Stretch: compare the estimate from the first 5 quadrats with the estimate from all class quadrats. How much did it change?

⚠ Safety

See the unit safety notes (ticks, allergies, no tasting plants, hand washing, boundaries). Carry quadrats pointing down.

Teacher notes and misconceptions

- The most common error is forgetting to convert per-quadrat to per-m² (dividing by 0.25 = multiplying by 4). Ask for units at every step.
- Some plants (grass, clover) are hard to count as individuals; that is what percentage cover is for.
- Keep the class data: lesson 5 can use it.

Lesson 3: Transects and gradients

Unit overview · Previous: Lesson 2 · Next: Lesson 4

Goal

Students sample along a line that crosses a change in conditions, record an abiotic factor with the plants, and describe a pattern carefully.

Materials

- Per group: a 20-30 m tape, a quadrat, a light meter or phone light-sensor app (same device all along the line), a ruler, plant identification sheet, recording table with one row per sampling point.
- A site with a gradient: from under a tree into open grass; across a trampled path into untrampled grass; or from a wall's shady side outwards.

Steps

Opening (5 min). "Lesson 2 asked how many. Today asks where, and why there?" Show a sketch of the site and ask what changes along the line.

Main activity (35 min, outdoors).

1. Lay the tape straight across the gradient. This is a **line transect**; placing the quadrat along it at regular points makes a **belt transect**.
2. Every 1 or 2 m (agree in advance; this is systematic, not random, sampling), place the quadrat on the same side of the tape and record:
3. which species are present (and counts or percentage cover for 2-3 common ones);
4. the abiotic factor: light reading at ground level, or for a path, the height of the grass / percentage of bare soil as a measure of trampling.
5. Take each light reading the same way: sensor flat, at the same height, not shaded by the student, all readings within a few minutes (clouds change light quickly).

Back indoors (5 min). Plot distance along the transect (x-axis) against light reading, and on the same distance axis, the count or cover of one species.

Discussion questions (with example answers).

- What pattern do you see? For example: "plantain cover was highest where the path was most trampled; grass height was lowest there."
- Does this prove trampling causes more plantain? No. It shows they go together along this line. Something else (soil compaction, moisture) could change too. An experiment or more sites would be needed.
- Why systematic points here, when lesson 1 said random? Here the question is about change along a line, so evenly spaced points make the pattern easier to see. The choice of line is still a judgement and should be described honestly.
- What could make the light readings unfair? Clouds passing, different heights, the student's own shadow, different phones.

Closing check (5 min, with answers).

1. Name one abiotic and one biotic factor you could record on a transect. (Abiotic: light, soil moisture, temperature, pH, trampling; biotic: number of a plant species, grazing marks, shading by a tree.)
2. Write one sentence describing a pattern that does not claim cause. (For example, "Where light was lower, there was less clover.")

Vocabulary

transect, gradient, abiotic, biotic, systematic sampling, correlation

Differentiation

- Support: one species only, with a ready-made table and axes.
- Stretch: repeat the transect 5 m to the side. Is the pattern the same? This is replication.

⚠ Safety

See the unit safety notes. Do not point any sensor at the Sun; do not look at the Sun.

Teacher notes and misconceptions

- Students often write "the plants need less light" for a shade-tolerant species. Prefer "this species was found more where light was lower".
- Ecological succession (bare ground to grass to scrub) can be introduced as an extension if the transect crosses a recently disturbed patch.

Lesson 4: Mark-recapture

Unit overview · Previous: Lesson 3 · Next: Lesson 5

Goal

Students estimate the size of a population that moves around, using a mark-recapture simulation, and state the assumptions behind the estimate.

Materials

- Per group: an opaque bag or tub with a secret number of dried beans (150-400; different per group; the teacher records each total), a marker pen (or a supply of beans of a second colour to swap in as "marked").
- Calculators.

Steps

Opening (5 min). "You can't put a quadrat on woodlice or fish; they move. How could you estimate how many live in a pond?" Introduce the idea: catch some, mark them, let them go, catch again later.

Main activity (30 min).

1. **First capture.** Take a scoop (or a handful) of beans without looking. Count them: this is **M**, the number marked. Mark each one (or swap each for a bean of the second colour). Return them all and mix thoroughly ("let the animals mix back into the population").
2. **Second capture.** Take a second scoop. Count the total, **C**, and how many of these are marked, **R** (recaptured).
3. **Lincoln-Petersen estimate:** $N \approx M \times C \div R$. Reasoning: the fraction marked in the second sample ($R \div C$) should be about the fraction marked in the whole population ($M \div N$).
4. **Chapman estimate** (less biased when samples are small): $N \approx (M + 1)(C + 1) \div (R + 1) - 1$.
5. Repeat steps 1-4 two more times (three rounds in all). Then the teacher reveals the true number.

Worked example. M = 40 marked; second sample C = 50, of which R = 8 are marked.

- Lincoln-Petersen: $40 \times 50 \div 8 = 250$.
- Chapman: $41 \times 51 \div 9 = 232.3...$, then $232.3... - 1 = 231.3...$, about 231.

Discussion questions (with example answers).

- What happens if you do not mix the beans? Marked beans stay together on top, so R is too large and the estimate is too small.
- What if R = 0? Lincoln-Petersen breaks (division by zero); the samples were too small. Chapman still gives a number, but it is very uncertain. Take bigger samples.
- List the assumptions for real animals. The population is closed (no births, deaths, arrivals or departures between captures); marks do not fall off; marking does not change survival or behaviour; marked animals mix fully; every animal is equally likely to be caught.

- Which assumption might fail for woodlice? For trapped mice? Woodlice may hide under the same log they were released from (poor mixing); mice may become "trap-happy" or "trap-shy", changing the chance of recapture.

Closing check (5 min, with answers). 30 snails are marked and released. Later 30 are caught and 6 are marked. Lincoln-Petersen: $30 \times 30 \div 6 = 150$. Chapman: $31 \times 31 \div 7 - 1 = 137.3 - 1 \approx 136$.

Vocabulary

mark-recapture, closed population, assumption, estimator, bias

Differentiation

- Support: a formula card with M, C and R labelled on a picture of two scoops.
- Stretch: use a spreadsheet to simulate 1,000 rounds with a known N and compare the average Lincoln-Petersen and Chapman estimates with N.

⚠ Safety

Dried beans: no eating; sweep up spills (slip risk). See README ethics notes before any work with real animals.

Teacher notes and misconceptions

- The Chapman form here is the one given in the Mark and recapture source. Both estimators assume a closed population.
- Students often mix up C and R. Use the words "caught the second time" and "recaptured (already marked)".

Lesson 5: Measuring diversity

Unit overview · Previous: Lesson 4

Goal

Students calculate Simpson's index of diversity for two sites, explain why evenness matters as well as the number of species, and complete the end-of-unit check.

Materials

- Class data from lessons 2-3 (species counts in quadrats from two areas), or the data below. Calculators or a spreadsheet.

Steps

Opening (5 min). Show two lists. Site A: 4 species. Site B: 4 species. "Which is more diverse?" Most say "the same". Then show the counts.

Species	Site A (mown lawn edge)	Site B (unmown corner)
Grass (counted as tufts)	30	12
Daisy	5	10
Clover	3	9
Plantain	2	9
Total N	**40**	**40**

Main activity (20 min).

Simpson's index of diversity used in this unit:

$D = 1 - \Sigma\, n(n-1) \div (N(N-1))$

where n is the number of individuals of each species and N is the total. D is 0 when every individual is the same species and gets closer to 1 as diversity rises.

Worked, Site A: - $n(n-1)$: $30 \times 29 = 870$; $5 \times 4 = 20$; $3 \times 2 = 6$; $2 \times 1 = 2$. Sum = 898. - $N(N-1) = 40 \times 39 = 1{,}560$. - $D = 1 - 898 \div 1{,}560 = 1 - 0.576 =$ **0.42**.

Students do Site B: $132 + 90 + 72 + 72 = 366$; $D = 1 - 366 \div 1{,}560 = 1 - 0.235 =$ **0.77**.

Then, if there is class data, compute D for the two areas sampled in lessons 2-3.

Discussion questions (with example answers).

- Both sites have four species. Why is B more diverse? B is more even: no species dominates. Picking two individuals at random from A, they are very likely both grass.
- What does D mean in words? The chance that two individuals picked at random (without replacement) are different species.
- Species richness vs evenness? Richness is the number of species; evenness is how equal their numbers are. Simpson's index combines both.

- Why might mowing lower diversity here? A guess to test, not a conclusion: frequent mowing may favour grasses that regrow from the base. We have one site of each, so we cannot separate mowing from other differences.

✓ End-of-unit check (25 marks, 20-25 min)

1. Explain the difference between bias and sampling variation, with one example of each from this unit. **(2)**
2. Six quadrats, each 0.25 m², give these counts of buttercups: 2, 5, 1, 0, 3, 1. The meadow is 250 m². Estimate the buttercup population. Show your working and units. **(4)**
3. A student's transect shows that moss cover is higher where light is lower. They write: "Shade causes moss to grow." Give two reasons this claim goes too far and one way to test it better. **(3)**
4. 60 beetles are marked and released. Later 45 are caught, of which 9 are marked. Calculate the Lincoln-Petersen and Chapman estimates. **(4)**
5. State two assumptions of mark-recapture. **(2)**
6. Calculate Simpson's index of diversity for Site C (four species, 5, 5, 5, 5 individuals) and Site D (17, 1, 1, 1). Explain the difference between them. **(8)**
7. Why can species richness alone be misleading when comparing habitats? **(2)**

Answer guide

1. Bias = a systematic error pushing estimates one way, for example choosing quadrats that look full (1). Variation = chance differences between random samples, for example two random sets of 10 squares giving different totals (1).
2. Total 12; mean 12 ÷ 6 = 2 per quadrat (1); density 2 ÷ 0.25 = 8 per m² (1); 8 × 250 = 2,000 (1); units stated (plants per m², plants) (1).
3. Any two (1 each): correlation is not causation; moisture or soil may also change with shade; only one transect / no replication; light readings may be unreliable. One test (1): repeat transects in other places, or an experiment that shades some marked patches and not others and follows moss cover.
4. Lincoln-Petersen 60 × 45 ÷ 9 = 300 (2: method 1, answer 1). Chapman 61 × 46 ÷ 10 − 1 = 280.6 − 1 = 279.6, about 280 (2: method 1, answer 1).
5. Any two (1 each): closed population (no births, deaths, migration between samples); marks not lost; marking does not affect survival or behaviour; marked individuals mix fully; equal chance of capture.
6. Site C: Σ n(n − 1) = 4 × 20 = 80 (1); N(N − 1) = 20 × 19 = 380 (1); D = 1 − 80 ÷ 380 = 0.79 (1). Site D: 17 × 16 = 272, other species 0, sum 272 (1); D = 1 − 272 ÷ 380 = 0.28 (1); correct rounding/working shown (1). Explanation (2): same richness (4 species) but C is perfectly even and D is dominated by one species, so two random individuals from D are usually the same species.
7. Two sites can have the same number of species but very different evenness (1); one dominant species with a few rare ones is less diverse in practice / more vulnerable (1). Also accept: richness depends heavily on sample size and effort.

Vocabulary

diversity, species richness, evenness, Simpson's index, dominance

Differentiation

- Support: a table with columns n, n − 1, n(n − 1) already set up.
- Stretch: compute Σ p² (with p = n ÷ N) for Sites A and B and compare with the n(n − 1) form. Why are they close but not equal? (The n(n − 1) form picks without replacement; the difference shrinks as N grows.)

⚠ Safety

None beyond normal classroom rules.

Teacher notes and misconceptions

- See the README note on index names: check the form your exam uses before students meet a different "Simpson's index" in a past paper.
- Students often think "more species" always means "more diverse". Sites A and B, and C and D, are built to challenge that.