Higher Applications Case Study 2: Ecology

APPLYING MATHS

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ECOLOGY

What Does an Ecologist Do?

An **ecologist** studies the relationship between **animals, plants, and their environment**. Their work involves understanding how ecosystems function, assessing biodiversity, and identifying environmental impacts. Here's a brief overview:

1. **Ecologist's Role**:
    - Ecologists work in various settings, including conservation organizations, NGOs, and the public/private sectors.
    - They analyze ecological systems, assess environmental changes, and propose land management strategies.
    - Their work can range from balancing environmental needs to designing habitat restoration plans.

2. **Ecological Surveys**:
    - Ecologists conduct **ecological surveys** to assess an area's environmental impact.
    - These surveys involve systematic data collection on:
        - **Vegetation**: Identifying plant species and their abundance (vegetation classification).
        - **Habitats**: Examining habitats like heathlands, lakes, woodlands, or coastal areas.
        - **Protected Species**: Identifying habitats for protected species (e.g., bats, birds, reptiles).
    - Ecologists use field observations, sampling techniques, and data analysis to understand the ecosystem.

3. **Importance of Ecological Surveys**:
    - Early awareness of ecological constraints helps developers plan.
    - Biodiversity Action Plans (BAPs) identify and protect threatened species.
    - Proper mitigation design ensures minimal disturbance to habitats.

In summary, ecologists play a crucial role in understanding and preserving our natural environment. Their surveys inform sustainable development and conservation efforts.

Mark, Release, Recapture

Ecologists sometimes employ a technique called 'Mark, release, recapture.'[1] This is a technique for estimating population size of an organism:

1. Take a sample from the population. Count and mark them (M).
2. Release the sample back into the population.
3. Allow time for marked individuals to mingle randomly within the population.
4. Take a second sample in the same way.
5. Count total number in the second sample (S) and number recaptured, i.e., those marked in the first sample (R).
6. Estimated population size (P) is calculated using the Lincoln Index:

$$P = \frac{M \times S}{R}$$

where
$M =$ Animals marked in first sample
$S =$ Total animals in second sample
$R =$ Recaptured in second sample

[1] British Ecological Society, https://www.britishecologicalsociety.org//wp-content/uploads/2022/09/maths-skills-for-biology.pdf

TOOTHED TOPSHELL

Task 1

A team of ecologists are investigating toothed topshell (*Osilinus lineatus*). They sampled an exposed shore and a sheltered shore, measuring the length of the shells in each.

(a) Briefly explain a sampling method the team could have used to ensure that they had a representative sample. (1)

10 toothed topshells were measured for the exposed shore sample, with measurements taken to the nearest millimetre. Using this data, the mean was calculated.

(b) Calculate the absolute error of the mean. (2)

Task 2 continued on next page…

Task 2

The data collected are represented in the table below. This dataset is also available in the file named "*topshell.csv*".

Habit Shell Lengths (mm)

Exposed	12	23	21	17	24	31	29	25	26	24
Sheltered	30	27	26	31	28	28	35	29	21	25

The ecologists want to determine whether there is a difference in the shell lengths of toothed topshells in exposed and sheltered shores.

(a) Represent the data in a suitable diagram. (2)

(b) What hypothesis test could be performed? State the null and alternative hypothesis and give one assumption for your test. (3)

(c) Perform your hypothesis test and comment on the result. (3)

GRASS SNAKES

Task 3

The team of ecologists also collected a sample of grass snakes (*Natrix natrix*). The team measured the mass and the length of each snake. The snakes were also marked before being released, so that the team could use the mark, release and recapture technique to estimate the population of grass snakes.

(a) Identify the dependent variable in the Lincoln index. (1)

The team collected 8 snakes in their first sample and marked them. In the second sample they captured 12 snakes, 4 of which were marked.

(b) Estimate the population size of the grass snakes. (1)

Task 3 continued on next page…

(c) Are the units in the Lincoln index consistent? Briefly explain. (1)

Some of the collected data are displayed in the table below. This dataset is also available in the file named "*grasssnake.csv*".

Length (cm)	10	15	23	46	29	70	70	120
Mass (g)	150	230	360	820	510	1120	1210	1820

(d) Produce a scatterplot showing mass on length. (2)

(e) Find the correlation coefficient between mass and length. (1)

(f) Interpret the correlation coefficient. (1)

(g) Find the equation of the regression line of number of mass on length. Interpret the slope and intercept parameters. (4)

(h) Estimate the mass of a snake with a length of 1.1 metres. (1)

PLANNING A SURVEY

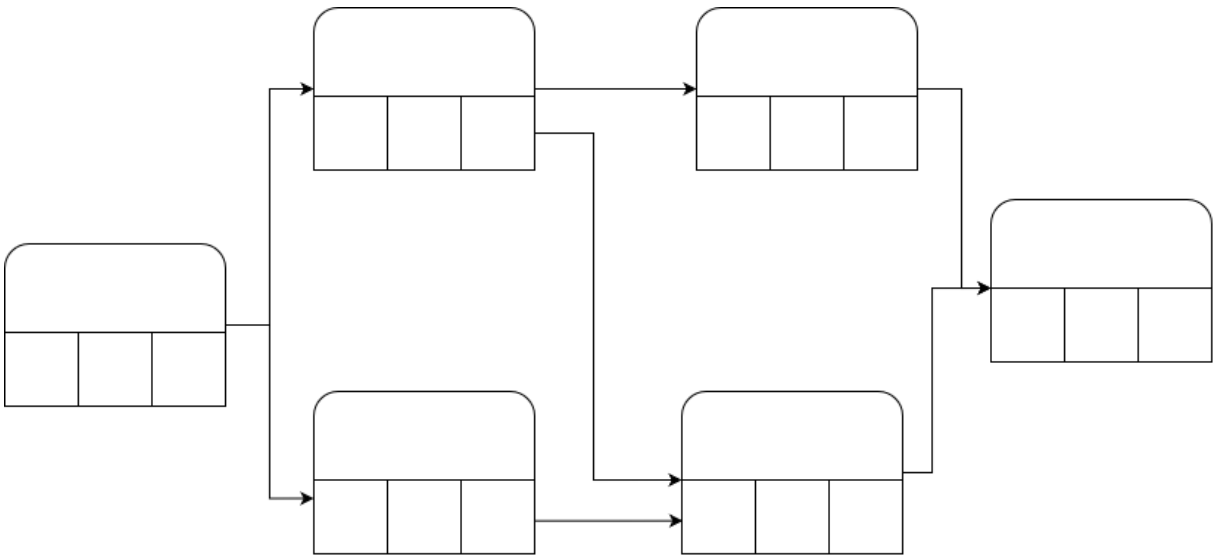
Task 4

A precedence table for conducting an ecological survey is given in Table 1.

Activity	Dependencies	Duration
Preliminary Ecological Appraisal (PEA)	None	2 days
Habitat Survey	PEA	3 days
Protected Species Surveys (PSS)	PEA	4 days
Data Analysis	Habitat Survey	2 days
Ecological Impact Assessment (EcIA)	Habitat Survey, PSS	2 days
Write up report	EcIA, Data Analysis	4 days

Table 1: Ecological Survey Precedence Table

(a) Complete the PERT chart for this project. (4)



(b) State the critical path. (1)

Task 4 continued on next page…

When completing the project, the habitat survey was delayed by 3 days.

(c) By how many days was the whole project delayed? (1)

FINANCE

Task 5

An ecological charity sets aside some money for a project. The money is in an account that pays interest at a rate of 4.5% per annum. Interest is paid monthly on the first of each month. Each month, on the first, the charity withdraws £500 from the account.
On the 1st of January, before the withdrawal is made, there is £12,000 in the account. The final withdrawal from the account is due to be on the 1st of March **the following year.**

(a) By creating a spreadsheet, calculate the balance in the account on the 1st of March ***the following year.*** *(5)*

Create a copy of your worksheet.

(b) Find the maximum amount the charity could withdraw each month. State the monthly withdrawal and the final withdrawal amount. (2)

END OF QUESTION SET.

ANSWERS

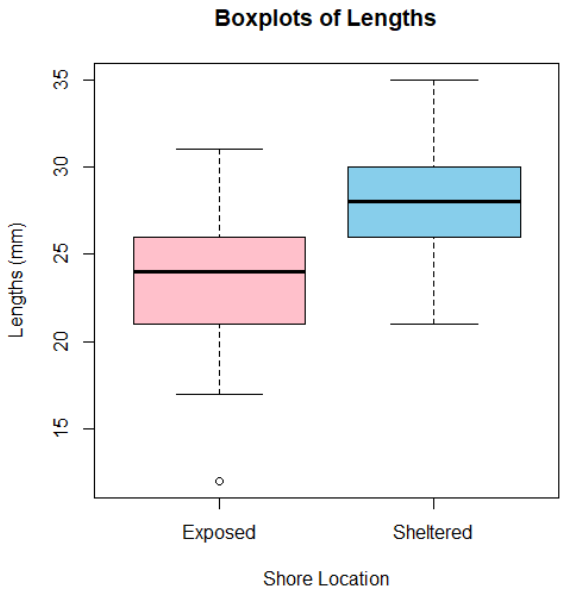
Question 1

(a)
- Any sensible description that states the sampling should be random. For example splitting the shores into different sections, randomly choosing which section to search in, and collecting the samples from there.

(b)
- Error of 0.5 millimetres for each topshell.
- The absolute error of the mean is also 0.5 millimeters. The sum of the lengths gives has an absolute error of $10 \times 0.5\,mm = 5\,mm$, and when divided by the sample size (10) the error is $0.5\,mm$.

Question 2

(a)
- Boxplots created.
- Axis labels and suitable title.



(b)
- Un-paired t-test.
- Null- There is no difference in lengths between topshells in exposed and sheltered shores. Alternative: There is a difference in lengths between topshells in exposed and sheltered shores.
- e.g. the data are normally distributed, the two groups are independent etc.

(c)
- Test completed.
- Comment on p value being less than 5%.
- Reject the null hypothesis and conclude there is a statistically significant difference between then lengths between topshells in exposed and sheltered shores.

```
> t.test(Exposed, Sheltered)

Welch Two Sample t-test

data:  Exposed and Sheltered
t = -2.2723, df = 15.807, p-value =
0.0374
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -9.2825389 -0.3174611
sample estimates:
mean of x mean of y
     23.2      28.0
```

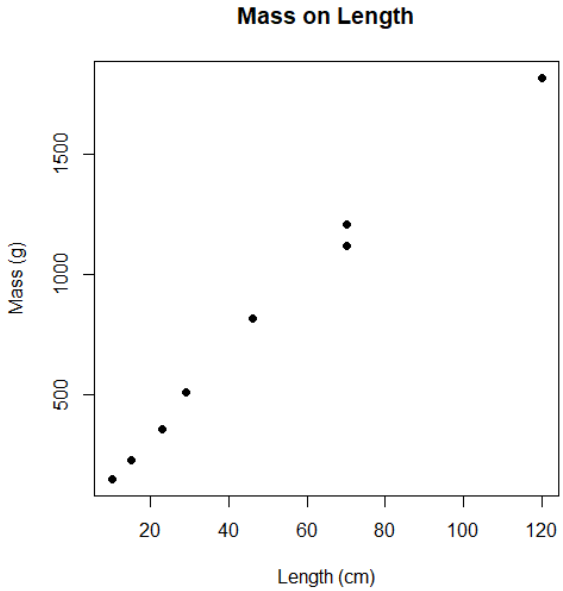
Question 3

(a) • P, the estimated population size.

(b) • 24 snakes.

(c) • Yes, because the units of M, S and R are all 'number of animals.' $\frac{Animals \times Animals}{Animals} = Animals$ which is the desired unit for P.

(d) • Scatterplot with mass as the y-variable.
• Labels and title.



(e) • 0.9949429

(f) • Strong, positive and linear.

(g) • Generate output.

```
> lm(Mass ~ Length)
```

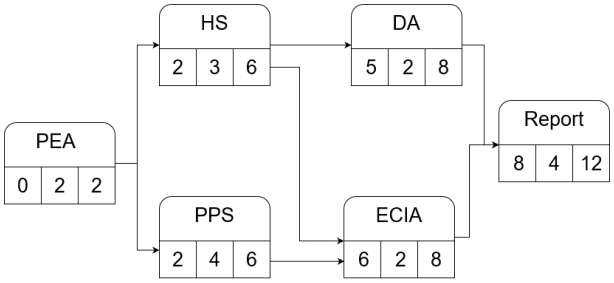
```
Call:
lm(formula = Mass ~ Length)

Coefficients:
(Intercept)       Length
      37.93        15.45
```

- $Mass = 37.93 + 15.45 \times Length$
- For every extra centimetre of length, the mass increases by 15.45 grams in the model.
- A snake of zero length would be predicted to have a mass of 37.93 grams.

(h)
- 1737.207 grams. Students may also estimate based on their graph.

Question 4

(a)
- Tasks in the correct boxes, including the duration.
- Forward scan correct.
- 3 correct answers in the backwards scan.
- All 6 latest finishing times correct.



(b)
- PEA, PPS, EcIA, Report.

(c)
- 2 days, because the habitat survey has one day of float time.

Question 5 See the file named "*finance.xlsx*"

(a)
- Creates a spreadsheet with a title, and key variables.
- Calculates the monthly interest rate.
- Applies monthly interest rate and the withdrawal amount.
- Spreadsheet is clear and easy to read.
- The ROUND function has been used. Answer: £4936.29

(b)
- The worksheet is copied and goal seek has been used to make the March balance £0.
- Monthly withdrawal of £820.70 and final withdrawal of £820.76.

CREDIT

Data used in this case study comes from the excellent A Level biology resource by the British Ecological Society.
Toothed Topshell photo: jacinta lluch valero CC BY-SA 2.0 Deed
Snake photo: Eichler, Andreas CC BY-SA 4.0, Wikimedia
Latex Template - Cleese Assignment, Vel (vel@LaTeXTemplates.com), License: CC BY-NC-SA 3.0.

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