Lecture 10: **Biodiversity**

Learning objectives

✓ Interpret power function models of real-world phenomenon

Scientific examples

✓ Biodiversity and species richness

Maths skills

✓ Understand the shape of power functions with powers between $\boxed{0 \text{ and } 1}$

✓ Solve power functions

linear → x^1
quadratic → x^2
power → x^p

4.4 (Super) powers

- Recall that linear and quadratic functions are examples of the more general group of *power functions*. Functions with different powers have graphs with different shapes, and hence can model different phenomena.

Question *4.4.1*

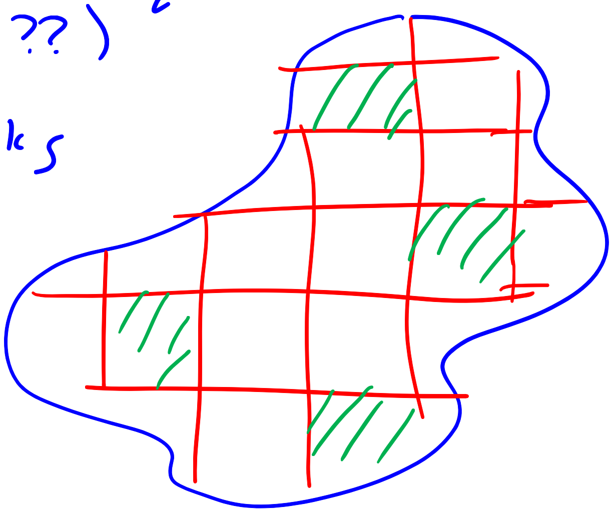
Lamington National Park in Queensland consists of about 20,000 hectares of rainforest. If you wanted to estimate the biodiversity in the park (the total number of different species found there), how might you do this?

Divide into squares

↳ count in each square
(resources ??)

↳ count near walking tracks

↳ count in random squares



Case Study 7: **Species-area curves and biodiversity**

Photo 4.3: Counting species in the field. (Source: DM.)

- Previously we discussed the abundance and distribution of a *single* species, *Bicknell's thrush.* Ecologists often study the *overall number of species* found in a region (sometimes called the *biodiversity* or *species richness*).

> **Species-area curves**
>
> In ecology, a *species-area curve* is a graph showing the number of distinct species observed, as a function of the size of the area surveyed.

Photo 4.4: Scribbly gum (*Eucalyptus racemosa*). Right: Scaly-breasted Lorikeet (*Trichoglossus chlorolepidotus*). (Source: PA.)

- Rather than performing a full count for an entire region, data from a smaller area can be extrapolated to estimate the regional species richness.

Example 4.4.2

Consider a four hectare property in eastern Brisbane. We wish to estimate the number of distinct, naturally occurring, native plant species (individuals greater than 2 m in height), that occur on this land. Suppose that 30 cells (or *quadrats*), each 10 m by 10 m, are selected at random and for each cell we record the occurrence of new species not seen in previous cells. Table 4.3 shows information on the previously unseen species, including the cumulative total count of species observed so far.

related to area

Cell(s)	New species observed	Count
1	*Eucalyptus racemosa, Acacia fimbriata, Banksia integrifolia*	3
2	*Eucalyptus tereticornis, Alphitonia excelsa*	5
3	*Acacia disparrima*	6
4	*Acacia leiocalyx, Lophostemon suaveolens*	8
5	–	8
6	*Glochidion sumatranum*	9
7	–	9
8	–	9
9	*Eucalyptus crebra*	10
10	–	10
11 – 15	*Banksia robur, Melaleuca quinquinerva*	12
16 – 20	–	12
21 – 30	*Allocasuarina littoralis, Angophora leiocarpa*	14

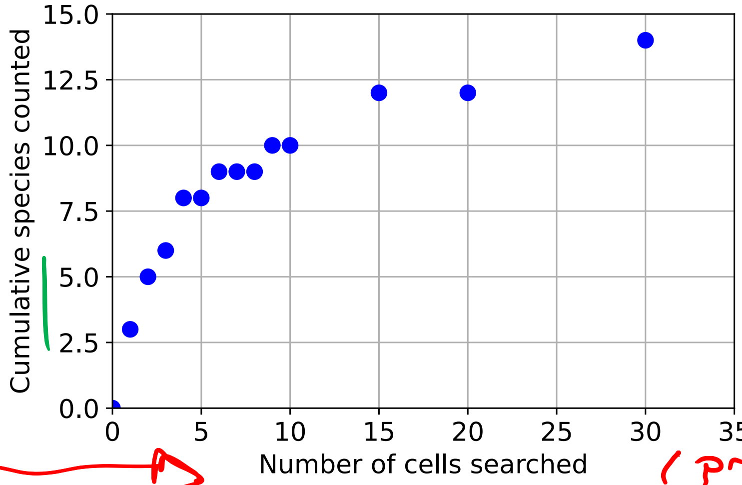
2 new species

1 new specie

no new species

Table 4.3: Information on additional observed species.

Figure 4.6 is a species-area curve summarising the data in Table 4.3.



(proportional to area)

Figure 4.6: The number of distinct tree species recorded on the property.

- The graph has a shape that is typical of many species-area curves: the number of distinct species initially rises rapidly as the area increases, but then rises less rapidly as the area becomes larger.

Equations for species-area curves

Species-area curves can be mathematically modelled using power functions, with power p between 0 and 1 (typically, p is between 0.2 and 0.5).

Their general form is $\boxed{S(a) = Ma^p,}$ where S is the number of species occurring as a function of the area a, and M and p are constants depending on the geographical location, resource availability and similar factors.

Question 4.4.3

With respect to a species-area curve:

(a) Discuss why species-area curves exhibit the general shape of this type of power function

- never decreases
- cumulative → as area increases it is harder to find new species
- initially find lots of new species
- no maximum (or limit)

(b) How might a species-area curve model impact on field sampling techniques?

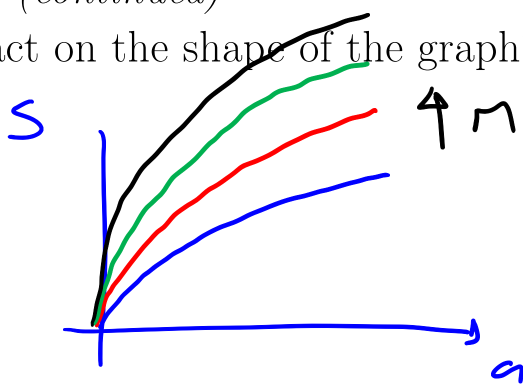
- reduce the number of cells that need to be searched
- improve accuracy of sampling – extrapolation (with caution)
- may be useful in other regions

$S = Ma^p$

Question 4.4.3 *(continued)*

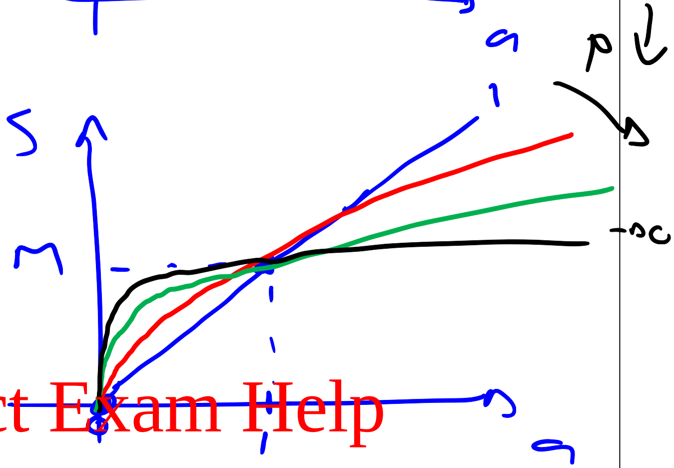
(c) How do the values of $\boxed{M}$ and $\boxed{p}$ impact on the shape of the graph?

M – vertical scale



p – curvature ($0 < p < 1$)

SOMSE



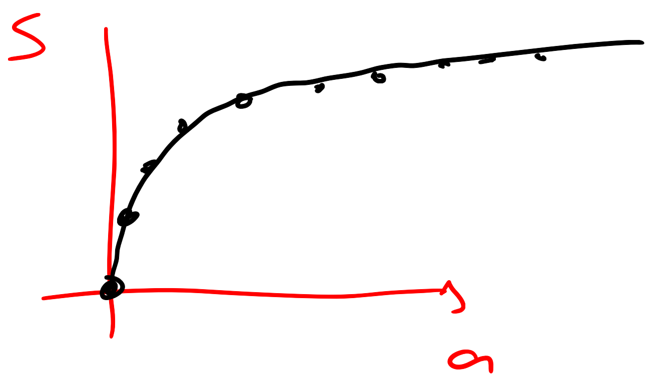
(d) What physical factors could affect the shape of the curve?

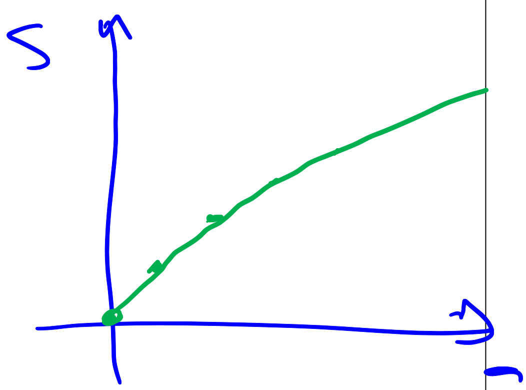
Density of species (varies)

Geography, climate, vegetation, habitat

evenly distributed

localised





$m = 5$

$p = 0.3$

Example 4.4.4

Figure 4.7 shows the graph of $S(a) = 5a^{0.3}$ and the species data from Table 4.3, where a is the number of 10 m by 10 m cells (hence related to area).

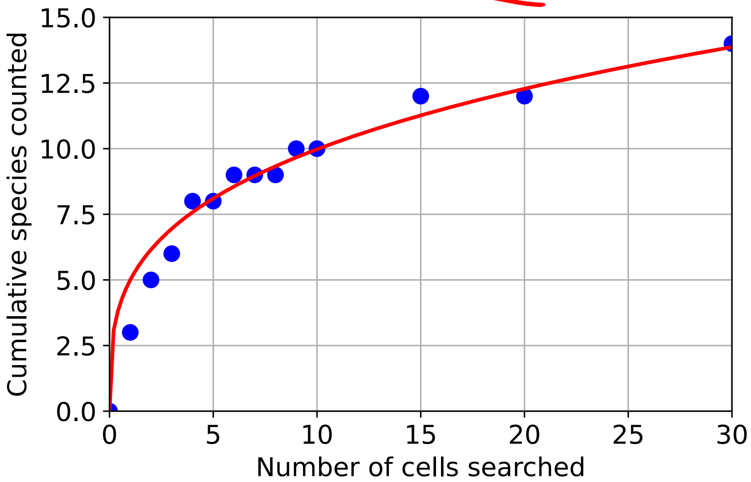


Figure 4.7: Modelling the species data from the 4 hectare property.

same model

Question 4.4.5

Assume that this question refers to native, naturally occurring plants more than 2 m high, growing on land ecologically similar to the four hectares of land in the previous example (that is, the model shown in Figure 4.7 is appropriate).

(a) Estimate the species richness (total number of species) on the four hectare (40,000 m^2) property.

Find S for an area of 40,000 m^2

Have $S = 5a^{0.3}$ a - no. cells

1 cell $= 10\text{m} \times 10\text{m} = 100\text{m}^2$

Number of cells $a = \dfrac{40{,}000\text{m}^2}{100\text{m}^2} = 400$

Thus $S = 5(400)^{0.3}$

$\simeq 30$

Approx 30 distinct species on 4 hectare

***Question** 4.4.5 (continued)*

(b) A typical conservation goal is to establish parks that preserve 10% of the representative land area. What fraction of species richness would be represented within such a park in the area near the four hectare property?

Find S_{new}/S_{old}

old - full park with area a_{old}

new - conservation area $a_{new} = \frac{a_{old}}{10}$

$$\frac{S_{new}}{S_{old}} = \frac{\cancel{S}(a_{new})^{0.3}}{\cancel{S}(a_{old})^{0.3}}$$

$$= \left(\frac{a_{new}}{a_{old}}\right)^{0.3} = \left(\frac{\cancel{a_{old}}/10}{\cancel{a_{old}}}\right)^{0.3} = \left(\frac{1}{10}\right)^{0.3} \simeq 0.5$$

(c) Many people believe that the figure in Part (b) is too low. If the goal is to retain 75% of species, what proportion of land should be preserved?

We want $\frac{S_{new}}{S_{old}} = 0.75$

Find a_{new}/a_{old}

$$\frac{S_{new}}{S_{old}} = \frac{\cancel{S}(a_{new})^{0.3}}{\cancel{S}(a_{old})^{0.3}} = 0.75$$

$$\left(\frac{a_{new}}{a_{old}}\right)^{0.3} = 0.75$$

$$\frac{a_{new}}{a_{old}} = (0.75)^{1/0.3} \simeq 0.38$$

$$x^2 = 4 \Rightarrow (x^2)^{1/2} = 4^{1/2} = 2$$

$\ln x = 2$

, 2012 – UQ co-authors including a PhD student Nature Clim.

Question 4.4.6

The paper [42] uses species-area curves to predict the reduction in species richness of vertebrate species in Mexican cloud forests. In Table 4.4, A_0 is the current area of cloud forest in two regions, A_1 is the predicted area in 2080 after climate change, and A_2 is the predicted area after climate change and forest clearing (here areas are measured in km^2). The corresponding numbers of endemic vertebrate species are S_0 (current), S_1 and S_2.

current clim. ch. clim. ch + clearing

Region	S_0	A_0	S_1	A_1	S_2	A_2
Oaxaca	26	5160		2326	9	65
Chiapas	3	6037	2	797	1	45

species # km^2

Table 4.4: Species-area model parameters for for two specific Mexican cloud forests.

(a) The species-area curve in Oaxaca is found to follow a power function with $p = 0.25$. Calculate the value of S_1 for Oaxaca.

$S = m A^{0.25}$

Use current values Oaxaca

$S = 26$, $A = 5160$ km^2

$26 = m(5160)^{0.25} \Rightarrow m = \dfrac{26}{(5160)^{.25}} = 3.1$

$S_1 = (3.1)(2326)^{0.25} = 21$

After climate change 21 species remain in Oaxaca.

(b) Which of Oaxaca or Chiapas would you suggest as the location for a new national park? Why? What other factors might influence your advice?

Oaxaca $\Rightarrow$ more species

But – cost?
endangered species
accessibility
value of land for other purposes.

End of Case Study 7: Species-area curves and biodiversity.