**Learning objectives**

✓ Interpret quadratic models of real-world phenomenon

✓ Critically analyse what information is being provided by a model

**Scientific examples**

✓ Climate change and Bicknell's thrush

**Maths skills**

✓ Use and interpret quadratic equations

Linear $y = mx + c$

$x^1$

$\downarrow$

$x^2$

# 4.3 Bend it!

## Case Study 6: **Climate change and Bicknell's thrush**



Image 4.2: Bicknell's thrush, *Catharus bicknelli*. (Source: en.wikipedia.org.)

Image 4.3: Adirondack mountains, USA. (Source: PA.)

***Example*** *4.3.1*

A paper [45] developed models for bird distributions using data from various altitudes, temperatures and locations in the north-eastern USA. The authors then used their models to predict the likely impact of rising temperatures on these distributions. Part of their study focused on Bicknell's thrush.

- The paper [45] built on earlier work that developed qualitative models Bicknell's thrush distributions with temperature.
- The authors combined these models to create a model for thrush distribution with respect to mean July temperatures across the breadth of their habitat.

***Example* 4.3.1** *(continued)*

- For the habitat in consideration, the study region was divided into cells, each 30 m by 30 m square.
- The study found that thrush habitats with July temperatures outside the range of 9.3 °C to 15.6 °C contained insignificant numbers of thrush.

Let $T$ be a temperature within the range 9.3 °C – 15.6 °C. The proportion $p(T)$ of cells containing thrush is closely modelled by the quadratic function:

quadratic

$$\boxed{p(T) = -0.0747T^2 + 1.8693T - 10.918.}$$

Data driven => phen.

=> maximum Quadratic => has a maximum or minimum



***Question* 4.3.2**



The graph of the function $p(T)$ is shown in Figure 4.5.



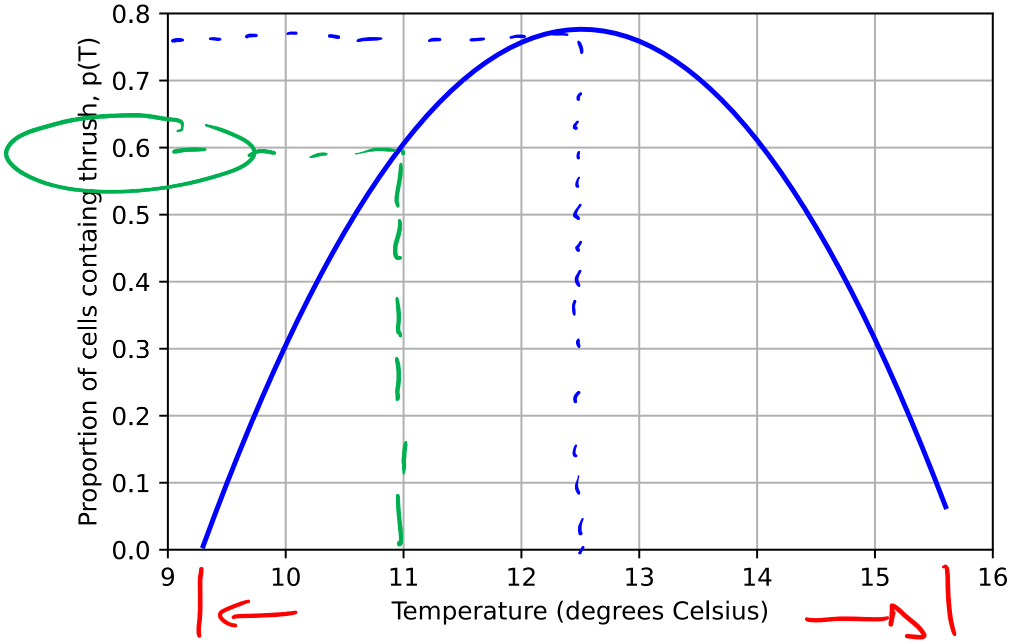



Figure 4.5: Distribution of Bicknell's thrush according to temperature.

***Question** 4.3.2 (continued)*

**(a)** What is the probability that a thrush will be found in a sample area in which $T = 11$ °C?

use graph, at $T = 11°C$, $p \simeq 0.6$ or 60%.

use equation $p = -0.0747(11)^2 + 1.8693(11) - 10.918 \simeq 0.606$

**(b)** From the graph, at what (approximate) value of $T$ is the thrush distribution most dense, and what is the (approximate) value of $p(T)$?

At the maximum $T = 12.5°C$

$p = 0.78$ or 78%.

**(c)** There is no value of $T$ for which $p(T) = 1$. Explain what this means and give reasons why it would happen.

If $p = 1$ => certain to find a bird in every square

Some squares may not have birds because predators, low density of birds, other species, no trees, lack of food/water



**(d)** Average temperature rises in the region over the next century are predicted to range from 2.8 °C under a low greenhouse gas emission scenario, to 5.9 °C under a high emission scenario.





**(i)** How would the graph in Figure 4.5 change if the average temperature rose by 2.8 °C? What if it rose by 5.9 °C? Explain your answers.

No change – unless adaption (unlikely under a rapid temperature change)

**(ii)** Assuming a substantial rise in average July temperatures, what factors may be a concern to resident Bicknell's thrush?

- heat stroke
- lack of food / resources
- no suitable habitat
- more competition

***Question** 4.3.2 (continued)*

Table 4.2 shows the total area of existing thrush habitat, and the estimated amount of viable habitat available after predicted temperature increases under the low emission scenario and the high emission scenario.

1 hectare = 100m x 100m

1 are = 10m x 10m

1 hectare = 100 are

| Scenario (°C) | Habitat (hectares) |
|---|---|
| (current) +0°C | 140000 |
| +1°C | 32000 |
| +2°C | 10000 |
| +3°C | 1000 |
| +4°C | 200 |
| +5°C | 75 |
| +6°C | 0 |

Table 4.2: Total areas of viable habitat available to Bicknell's thrush under various climate change scenarios.

**(e)** What is the fraction of suitable habitat that would remain available for the thrush population if temperatures rise by 2.8 °C or 5.9 °C?



For 2.8°C increase ≈ 3°C increase

$\frac{A(+3°C)}{A(0°C)} = \frac{1000}{140000} \approx 0.007$ or 0.7%



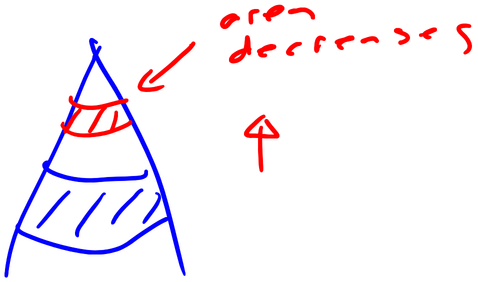
For 5.9°C ≈ 6°C



$\frac{A(+6°C)}{A(0°C)} = \frac{0}{140,000} = 0$

**(f)** If temperature increases occur at the higher end of predictions, what kind of survival strategies might the thrush utilise?

- relocate
- perish
- adapt ??




End of Case Study 6: Climate change and Bicknell's thrush.

### *Question* 4.3.3

How can we be sure that the results of the study provide a good guide to the actual behaviour of the ecosystem? What idealisations are made in the model?

On page 528 of their paper, Rodenhouse et al. [45] say:

> *We foresee no potential benefits associated with climate change for mountain-breeding species. Although the prospect for retaining these species throughout most of the Northeast is not good under any of the projected scenarios, we also cannot predict with any precision when population declines and losses will occur. Predicting the pattern and timing of such losses would require knowing precisely how much temperature will change and where, the effects of site-specific factors such as slope and aspect, how disturbance regimes within spruce-fir forest may change, and last, the effects of climate change on montane food webs. We simply do not yet know enough about the ecology of montane biological communities to make more than qualitative projections of change for most species of this habitat type.*



model = idealisation / simplify / distort

They explain that:

- they don't know how fast new types of trees will replace old
- they don't know how different species will adapt to new habitats
- they can't factor in 'dramatic and unexpected' events

Does this mean that their model of the effects of climate change on birds in Northeastern USA is wrong?

Depends on what is meant by "wrong"
Can still be useful - at least qualitatively