Biogeographic patterns and climate change

This practical exercise was developed by Dr Simon Connor at the School of Geography and Environmental Science (SGES), Faculty of Arts, Monash University. *Except as provided in the Copyright Act 1968, this work may not be reproduced in any form without the written permission of SGES.*

Introduction

Australia's unique biota has evolved to cope with a variable climate and nutrient-poor soils. Many species have adaptations to high temperatures, frequent drought and fire. But what might happen to Australia's plants and animals in the greenhouse-enhanced climates of the future? We need to know in order to manage Australia's biodiversity.

In Victoria, average temperatures have risen by about 1°C since the 1950s. By 2070, climate models predict that temperatures will rise by a further 1.5–3°C, depending on what action is taken to lower greenhouse gas emissions in the meantime. Heat waves are expected to increase and average rainfall is expected to decline. All of these changes could have major implications for species distributions in Victoria.

So how can we predict what will happen to plants and animals in the future? One way is to look at how species are distributed under the current climate. The range of climates occupied by a species is called the *bioclimatic niche* or *climatic envelope*. Once we work out the current niche, we need to know whether the location of this niche will move as the climate changes. If so, then the species will either have to migrate, adapt or go extinct. Obviously extinction is a bad outcome for biodiversity! Can species migrate or adapt fast enough to cope with rapid climate change? And, even if they can, will there be sufficient suitable habitat for migration paths?

With these questions in mind, the aims of this practical are to:
- Examine species distributions in relation to the current climate
- Look at how species distributions have reacted to climate changes over the last 10,000 years
- Make some preliminary predictions about how species might respond to future global warming

Remember that climate is only one factor that influences species distributions: soils, topography, geological history, competition, genetic diversity, human impacts and many other factors are also important. Species may also react to climate change in unpredictable ways. Keep this in mind as you work through the practical exercise.

## The Atlas of Living Australia (ALA)

This practical is based on the Atlas of Living Australia (www.ala.org.au). The ALA is a major national collaboration between museums, herbaria, universities, community groups and the CSIRO. It brings together all of the known records on Australia's flora and fauna, with sophisticated mapping and modelling tools for analysis. It's a fantastic resource for Australia's biodiversity and it's free for everyone to use.

*N.B. This practical can be completed <u>with or without</u> a computer.*

Section 1: Animal distributions in the current and future climate

Let's use the ALA to map the distribution of two of the most common Australian marsupials found in Melbourne backyards – the Common Ringtail Possum (*Pseudocheirus peregrinus*) and the Brushtail Possum (*Trichosurus vulpecula*).

[Try it yourself: type the common name or scientific name into the search tool; when you have the search results, click on the scientific name to get the occurrence record; then click the 'map & analyse records' button under the map; you can click on any of the points on the map to get more information about that record, including complete bioclimatic data for that location]


Pseudocheirus peregrinus   *Trichosurus vulpecula*
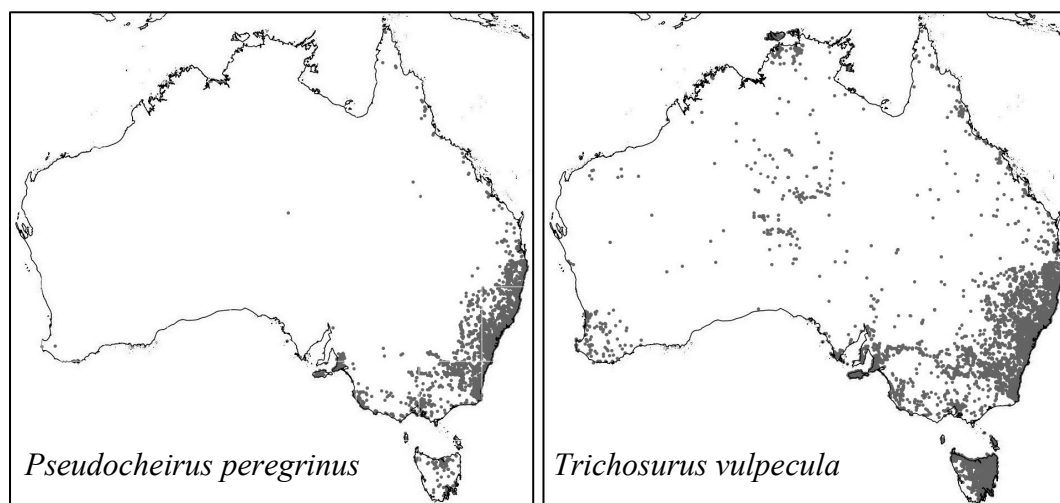
1. Compare the two distribution maps above with the climate maps below. Which species of possum has the **largest** bioclimatic niche? Use its common name:
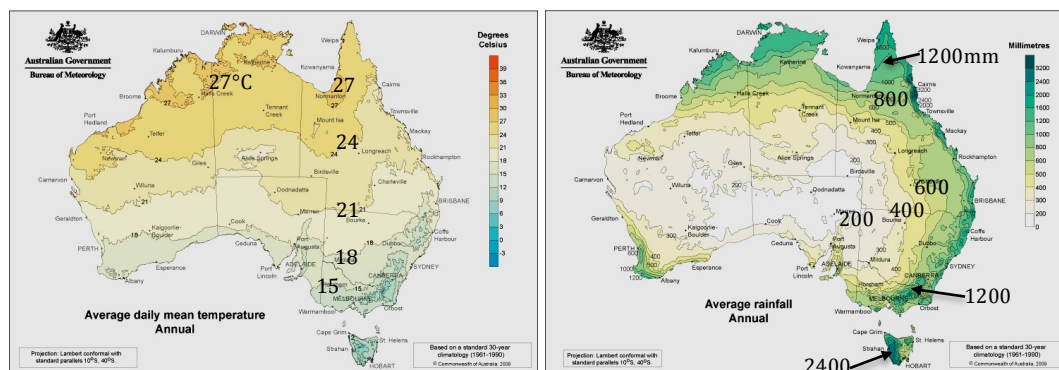
Species occurrences can be presented in geographical space (as above) or in climate space, as in the following scatterplots (below). These represent each of the records for the two possum species in terms of average annual temperature and precipitation. These variables are often important in species distributions, but the ALA lets you experiment with hundreds of variables to see which ones affect different species.

[Try it: on ALA's main page, select Mapping & Analysis, then Tools, Scatterplot; select extent (e.g. Australia); search for the species of interest; select 'no highlight'; then select the x- and y-axes you want for your scatterplot. The plot may take a few moments to load. The plot is interactive, so you can drag a box around any of the dots and they will be highlighted on the map]

Common Ring-tailed Possum

Brushtail Possum
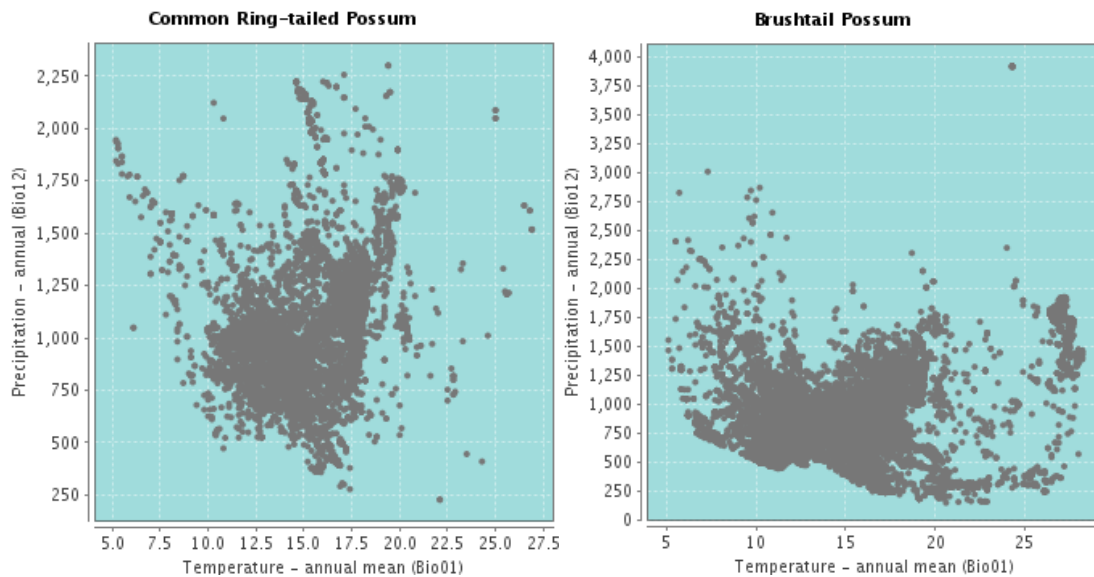
Notice that each graph has a central cluster that represents the species' core range. The surrounding scatter represents more marginal populations or isolated occurrences.

2. Draw an ellipse or polygon around the core ranges of the two possum species. Is there a difference between the two? Use temperature and precipitation values (e.g. maximum and minimum) to detail your answer:

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3. Below are some climatic data for Melbourne, Adelaide and Sydney. Using these numbers, plot the climatic position of the four cities on the scatterplots above. Label each of the points with the first letter of the city's name (i.e. M, A, S).

Current climate	Mean temperature (°C)	Annual precipitation (mm)
Melbourne	14.7	642
Adelaide	16.9	518
Sydney	17.9	1077

Now let's see what happens to our possums with future climate change. If carbon emissions are not reduced significantly, by 2070 temperatures in Melbourne and Adelaide are predicted to be about 3°C higher and precipitation 20% lower. In Sydney, temperatures are predicted to be 3°C higher and precipitation 10% lower.

4. Use current climate data in the table above to work out temperature and precipitation predictions for 2070 (e.g. for Melbourne, it is 14.7 + 3 = 17.7°C). Write the predicted 2070 values in the table. Then plot them on the scatterplots. Label them appropriately (e.g. M-2070).

5. Do any of the climate estimates for 2070 fall outside the current core range of either of the possum species? What could this mean for its survival in that area?

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6. If you were in charge of a government programme to conserve the two possums in SE Australia, which species and which areas would be your main priorities?

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Section 2: Changing plant distributions under changing climates

Animals like possums are relatively mobile, so they can move quite easily to new locations if the climate becomes unsuitable in their current habitat. But for some species, like slow-growing trees that live for hundreds of years, that is not so easy.

Let's consider the Myrtle Beech (_Nothofagus cunninghamii_). This is a big tree that grows in the temperate rainforests of Victoria and Tasmania. In Victoria, most Myrtle Beech populations are restricted to moist valleys that are protected from fire. The trees do not tolerate the frequent fires experienced in the surrounding eucalypt forests. Southern Beech cannot migrate easily, given its slow growth rate and poorly dispersed seeds. In the past it was much more widespread – the fossil record shows that _Nothofagus_ has contracted over millions of years due to past climatic changes.
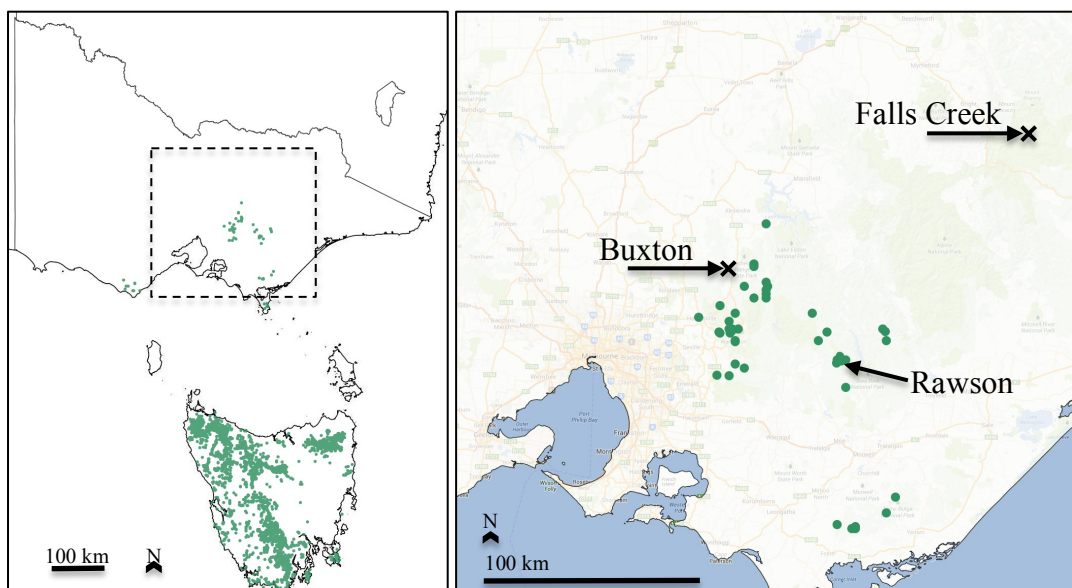
The maps above show the present distribution of *Nothofagus cunninghamii* in Southeastern Australia and Victoria. Until 6000 years ago, fossil evidence proves that *Nothofagus* was present at Buxton, a place where it no longer occurs.

Let's look at how climate change might have affected Myrtle Beech to find out why it has disappeared from Buxton. The table below gives the minimum and maximum values for the climatic envelope of Myrtle Beech, as well as the current climate at Buxton (where the plant occurred until 6000 years ago) and Falls Creek (an area of the Australian Alps where the plant has never occurred during the last 12,000 years).

Climatic parameter	Myrtle Beech bioclimate		Present climate	
	Minimum	Maximum	Buxton	Falls Ck.
Mean annual temperature	4.7	13.9	13.5	7.8
Mean min. temp., coolest month	-2.9	6.4	2.7	-2.1
Mean max. temp., warmest month	14.8	24.8	28.0	20.8
Mean temperature, wettest quarter	0.4	10.6	7.9	1.7
Mean temperature, driest quarter	9.2	18.5	19.3	12.9
Mean annual precipitation	930	3523	1096	1760
Mean precipitation, wettest month	92	353	123	228
Mean precipitation, driest month	51	188	55	78
Mean precip., wettest quarter	267	1043	351	621
Mean precipitation, driest quarter	169	649	175	253

7. Examine the table above, comparing the bioclimatic niche of Myrtle Beech to the climate at Buxton. Circle the climatic parameters that appear prevent Myrtle Beech from growing around Buxton today. What does this tell you about the climate around Buxton until 6000 years ago?

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8. What other (non-climatic) factors might explain the disappearance of Myrtle Beech from Buxton? List as many as you can think of.

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9. Is the climate at Falls Creek suitable for Myrtle Beech today? If so, what factors might explain its absence there?

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Section 3: Rare or endangered species and climate change

In this final section we will look at how climate change might affect rare plants and animals – the ones that are usually considered to be at most risk of extinction under greenhouse-enhanced climates. Let's consider two species that live in the snowfields of the Australian Alps. The Bogong Eyebright (*Euphrasia eichleri*) is a small herb with beautiful flowers that grows only on the treeless meadows of the Bogong High Plains near Falls Creek. Its conservation status is currently listed as 'vulnerable'. The Mountain Pygmy Possum (*Burramys parvus*) also lives around Falls Creek in rocky scree slopes. It is listed as 'critically endangered' in Victoria and 'endangered' in New South Wales, where it also lives around Mt Kosciuszko (Australia's highest mountain, 2228 m above sea level). Victoria's highest peak is Mt Bogong (1986 m).

Using the ALA, we can generate maps of the bioclimatic niches of these species. Below are maps for the Bogong Eyebright and Mountain Pygmy Possum.

[You can make these maps in the ALA using the Predict function in Mapping & Analysis… but it can be a slow process. These ones were based on 5 environmental layers that best explain the majority of species distributions in Australia: precipitation of the driest quarter, precipitation seasonality, radiation seasonality, radiation of the warmest quarter and moisture index]
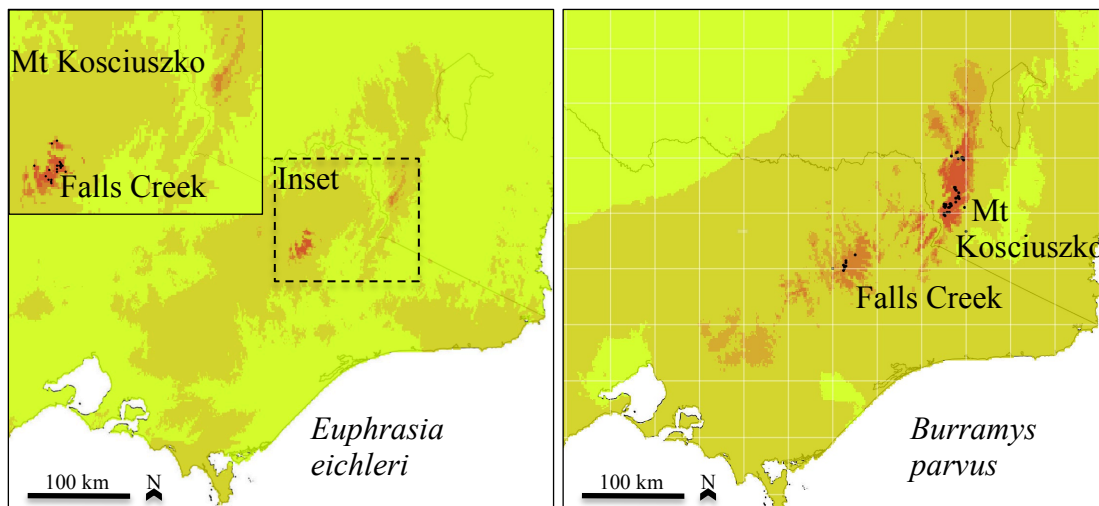
The shading in the background represents bioclimatic suitability: the darker the shade, the more suitable the climate of that area. Black dots represent recorded occurrences.

10. Which species do you think may be more sensitive to climate change? Why?

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11. Looking at the map, which population of the Mountain Pygmy Possum seems to be more at risk from climate change: the one in Victoria or the one in New South Wales? Explain your answer.

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It is assumed that many species will migrate upwards to higher elevations in response to greenhouse-induced warming. This is because temperature decreases at a rate of approximately 6.5°C per 1000 m of elevation increase – the *environmental lapse rate*. We can see this quite clearly on the following scatterplot, which graphs temperature and elevation of *Burramys parvus* and *Euphrasia eichleri* records in Australia.
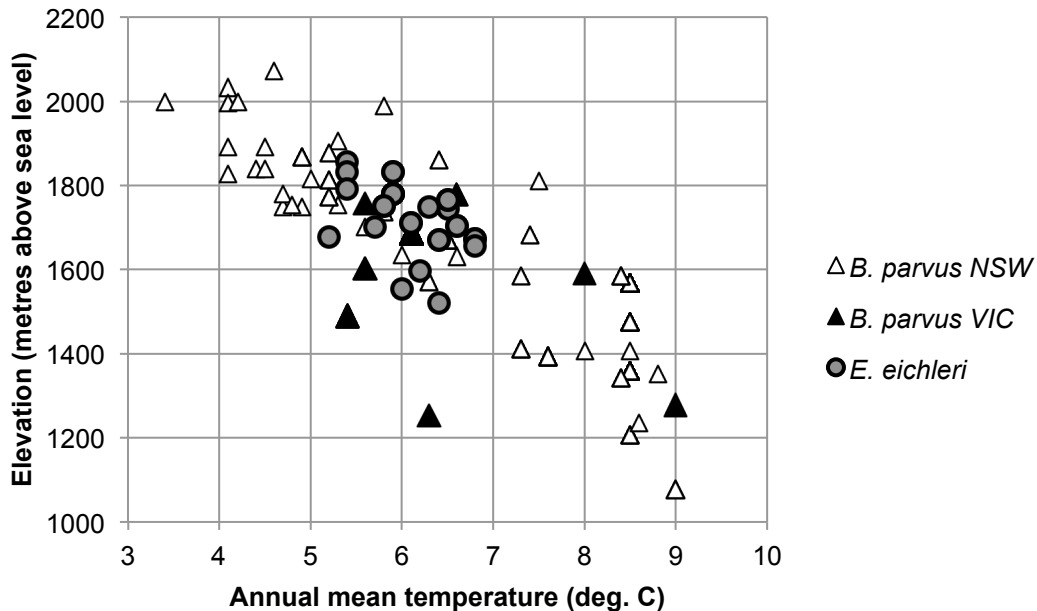

12. Draw a diagonal line through the points to represent the environmental lapse rate. Then draw a horizontal line at 1986-m elevation to represent Mt Bogong. This is the highest point in Victoria to which species could migrate.

13. What is the temperature where the two lines cross?

14. Now let's add climate change. Add 3°C to your answer above and draw a vertical line up. At what elevation do the vertical and diagonal lines cross?

15. Explain the bioclimatic significance of this elevation:

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16. Calculate the elevation difference from adding 3°C: 1986 - _____ = _____

17. Add this number to the current ranges below to estimate the future ranges:

	Current range		Future (+3°C) range	
	Max. elevation	Min. elevation	Max. elevation	Min. elevation
E. eichleri	1850 m	1500 m		
B. parvus (VIC only)	1750 m	1250 m		

18. Using the data in the table, use shading/hatching to indicate on the topographic map the approximate current elevation range of the two species. Circle the approximate future ranges for each species. Don't forget to include a legend.

Bogong High Plains, NE Victoria

5 km   N

Only contours above 1000m shown
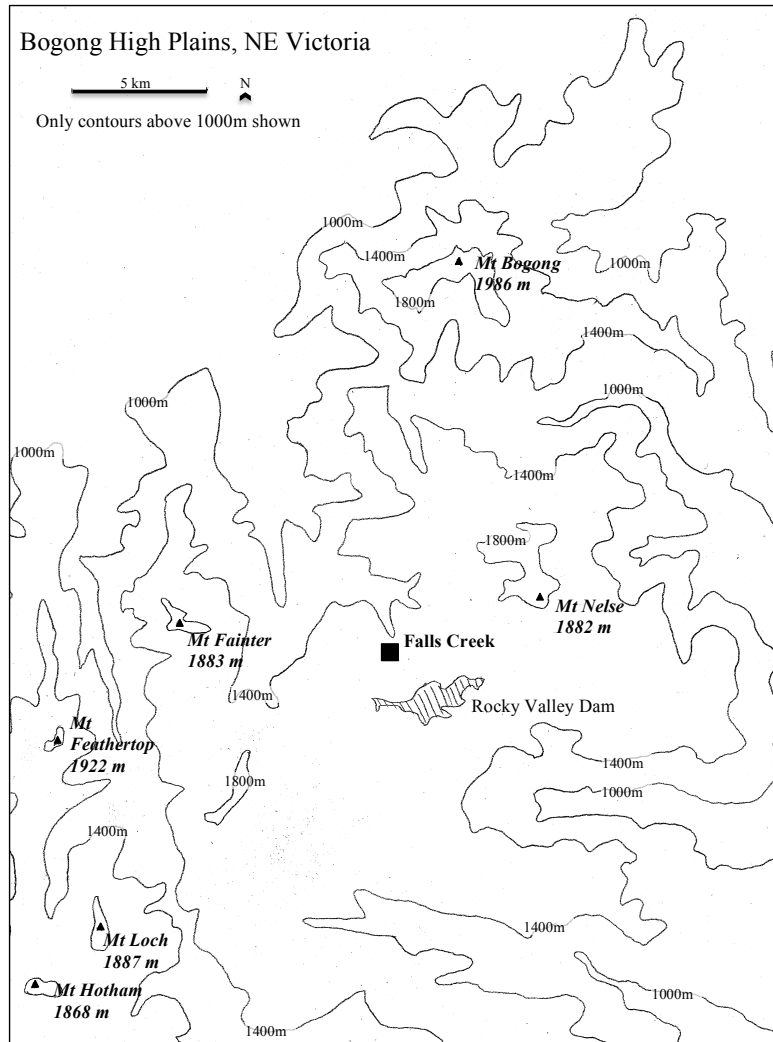
19. Which species do you think is the most vulnerable to climate change? Why?

20. Congratulations! You are now a bioclimatic modeller. But climate is only part of the story. What other factors might you need to consider if you were drawing up a management plan to prevent the extinction of these two species?