Queensland's Legacy of Diversity

Year 10 Biological Sciences

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Queensland Museum Learning Resources

As the state's foremost collecting institution, Queensland Museum celebrates the stories of Queensland from prehistoric giants to modern achievements and scientific discovery spanning millennia. Queensland Museum comprises of four public sites, Queensland Museum Kurilpa, Queensland Museum Tropics, Queensland Museum Cobb & Co, and Queensland Museum Rail Workshops. It also hosts the Collections and Resource Centre for collection storage and research.

The collection continues to grow through new acquisitions of objects and specimens that are relevant to Queensland. These elements of Queensland 's heritage form the basis for research projects, exhibitions, and education programs. We use them to better understand key global issues – from climate change to nature conservation, and from cultural understanding to community histories.

Queensland Museum provided teachers and educators with practical, high-quality, and engaging resources to use in the classroom, connected to Queensland Museum stories, research, collections and exhibitions.

Future Makers

These resources have been developed through Future Makers, an innovative partnership between Queensland Museum and Shell's QGC business aiming to increase awareness and understanding of the value of science, technology, engineering and maths (STEM) education and skills in Queensland.

This partnership aims to engage and inspire people with the wonder of science, and increase the participation and performance of students in STEM-related subjects and careers – creating a highly capable workforce for the future.

Cover Photo: Dorsal view of dung beetle *Onthophagus parvis* Ⓒ 2023 Queensland Museum – Lily Kumpe.

Australian Curriculum Alignment

Year 10 – Biological Sciences

Strand	Sub-strand	Content Descriptor	AC code
Science Understanding	Biological Sciences	Use the theory of evolution by natural selection to explain past and present diversity and analyse the scientific evidence supporting the theory	AC9S10U02
Science Inquiry	Questioning and Predicting	Develop investigable questions, reasoned predictions and hypotheses to test relationships and develop explanatory models	AC9S10I01
	Evaluating	Assess the validity and reproducibility of methods and evaluate the validity of conclusions and claims, including by identifying assumptions, conflicting evidence and areas of uncertainty	AC9S10I06
	Communicating	Write and create texts to communicate ideas, findings and arguments effectively for identified purposes and audiences, including selection of appropriate content, language and text features, using digital tools as appropriate	AC9S10I08

Queensland's Legacy of Diversity

Teacher Background Information

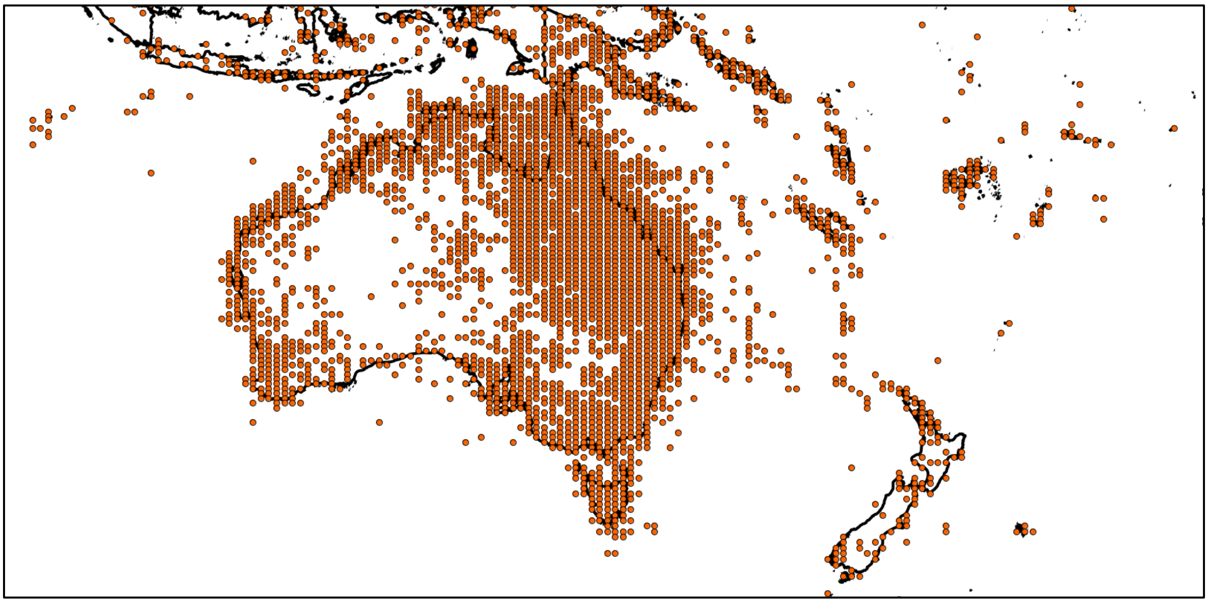
Queensland is Australia's most biodiverse state. This biodiversity is actively being studied by Queensland Museum scientists to help understand our native ecosystems and protect our environment. Queensland Museum contributes a large amount of data from specimens in the collection to the Atlas of Living Australia, which is an online repository of biodiversity data compiled from a range of institutions as well as *iNaturalist* observations contributed by citizen scientists.

This lesson was inspired by research conducted by Dr Nicole Gunter, Scientist and Curator of Entomology at Queensland Museum, on the biogeographic drivers of speciation in native Australian dung beetles. Over the last decade her lab has generated a DNA sequence library for thousands of dung beetles collected across the continent that is used to assess species boundaries and explore their evolutionary history.

Surprisingly, approximately 70% of Australian invertebrate species are currently not described, meaning they lack a scientific name and we don't know where they are distributed or how to identify them. By working to describe Queensland's dung beetles, Dr Gunter is giving these species names which will, in turn, help to conserve them.

Although the biological species concept is traditionally taught in school, it is impractical to test in reality. Instead, this lesson encourages students to think beyond the biological species concept and consider morphological, genetic and biogeographic species concepts to assess species boundaries of two closely related dung beetle species in Northern Queensland, *Coptodactyla nitida* and *Coptodactyla storeyi*. Students will utilise data available on the Atlas of Living Australia Spatial Data Portal to investigate climatic and biogeographic factors that may have caused them to speciate.

Although *C. nitida* and *C. storeyi* do not share habitat, their ranges border one another at the southern edge of the 'Black Mountain Barrier', which is a known biogeographic barrier. This geographic feature created an area of low-rainfall woodland during the Pleistocene epoch, separating rainforest species to the north and south. This woodland has contracted and expanded through time, causing populations to separate and then reconnect. How long these populations remained separate influenced if they became separate species.



Queensland Museum has contributed over 900,000 records to the Atlas of Living Australia, 875,845 of which are depicted here. Image generated from Atlas of Living Australia, map data © OpenStreetMap, imagery © CartoDB

It was proposed by Dr Christopher Reid in 2000 that the Black Mountain Barrier was an important driver of speciation in *C. nitida* and *C. storeyi* as described in the paper "A complex of cryptic species in the genus 'Coptodactyla' Burmeister (Coleoptera: Scarabaeidae: Coprini)", published in *Memoirs of the Queensland Museum*. Dr Reid noted that morphological differences between these species are minimal but suggested that their status as independent species has been maintained due to geographic separation, including slight altitudinal differences where these species almost meet. Each species also seems to prefer different habitats, though both can be found in rainforest and open eucalypt and casuarina forests. Dr Gunter and associates' later research into species boundaries based on DNA showed minimal differences and raised the question – are they two species or one?

The complex interactions of populations through time within a dynamic landscape where forests expand and contract with historical climate change can make interpreting species boundaries challenging. As such, the relationship between *C. nitida* and *C. storeyi* provides an excellent case study to illustrate the concepts of natural selection, geographic isolation and species boundaries. In this lesson, students analyse evidence for the theory of natural selection by using predictive habitat models to assess the effect of spatial and climatic variables (such as precipitation and elevation) on the distribution of the dung beetle species *Coptodactyla storeyi* and *Coptodactyla nitida*.

Notes:

1. In order to complete this lesson, students will need to create an account to access the Atlas of Living Australia Spatial Data Portal, which can be found here: https://spatial.ala.org.au/.
2. The status of *C. nitida* and *C. storeyi* as one species or two is currently unclear. Although they are still officially defined as two species, the barrier between them is small and tenuous. Their habitats have expanded and contracted several times over many thousands of years and, although they do not currently share habitat, they probably did in the past and may do so again in the future. As such, students should recognise that any conclusion they draw from the information available is valid, as long as they can justify it.
3. This lesson contains several habitat predictions that are represented as 'heatmaps' (e.g. page 11). They show the areas in Australia that are predicted to be suitable habitat for *C. nitida* or *C. storeyi*, based on a range of spatial and climatic factors. The best way to interpret these is to look for the areas with the strongest predictions (colour blue for very strong and dark red for reasonably strong). These areas should match the species observations (black dots) very closely. If they do not, the model should be considered inaccurate.

Queensland's Legacy of Diversity

The Theory of Evolution by Natural Selection states that organisms with traits better suited to their environment will survive and reproduce more than others. That is, if some organisms can survive better than others in an environment, they are more likely to live long enough to be able to breed, meaning their DNA continues into the next generation. In this way, the DNA of organisms well suited to their environment becomes more common and other DNA is more likely to disappear. This process can eventually lead to speciation. There are abiotic (non-living) factors that can affect natural selection and these might not affect the phenotype (physical characteristics) of a species and could, instead, affect things such as their tolerance to heat or moisture.

Speciation can be defined as a population of organisms splitting into two or more distinct populations that become reproductively isolated. How scientists define a 'reproductively isolated' population (i.e. a species) is a commonly debated question, however it is usually accepted that a population is distinct if it does not interbreed with another population. In this way, a species is often defined as a population of organisms that cannot interbreed with another and produce fertile offspring. This is called the biological species concept.

In practice, however, the biological species concept is not feasible to test. For example, it is not reasonable or practical to check if two populations of whale interbreed because we cannot be present for every mating event that they may perform and then observe if their offspring can breed. Instead, scientists usually use a combination of three other species concepts to test species boundaries:

1. The morphological species concept where species are defined based on differing phenotypes.
2. The genetic species concept where species are defined based on how similar their DNA is.
3. The biogeographic species concept where species are defined based on their habitats and lifestyles.

A real-world example of this happening from Queensland are the species *Coptodactyla nitida* and *Coptodactyla storeyi*, two almost-identical dung beetles from Northern Queensland. Although they are currently classified as separate species, the only way to identify them physically is to dissect them and examine slight differences in their internal characteristics.

Coptodactyla storeyi has been collected from Cape Flattery south to Cairns and Mareeba and is commonly found in rainforest but also in open eucalypt and casuarina forest, while *C. nitida* is commonly found in open eucalypt and casuarina forest (and occasionally in rainforest) and known from Mareeba south to Paluma.

Coptodactyla brooksi. A member of the horned clade of genus Coptodactyla. The two species examined in this lesson are so understudied that very few images of them exist. © Queensland Museum – Geoff Thompson

It is thought that the two species diverged due to geographic isolation and allopatric speciation, which is when a population is physically separated by a geographic feature of some kind (e.g., a mountain, a river or an uninhabitable area). In this case, the formation of the Black Mountain Barrier potentially caused the geographic isolation that may have led to the speciation of *C. nitida* and *C. storeyi*. This was proposed in the 2000 paper by Dr Christopher Reid, "A complex of cryptic species in the genus 'Coptodactyla' Burmeister (Coleoptera: Scarabaeidae: Coprini)", published in *Memoirs of the Queensland Museum*.

The Black Mountain Barrier, also known as the Black Mountain Corridor, is a section of dry woodland that formed to the north of Cairns in the Pleistocene epoch due to changes in the climate caused by the surrounding geography. This area is a biogeographic barrier that divides the nearby rainforest habitat into two. Fossil evidence shows that the dry woodland was more expansive 38,000 years ago but contracted 9,000 years ago, allowing more connectivity between rainforest in the area. The expansion and contraction of rainforest highlights the changing climate in the Pleistocene and the dung beetles would have needed to adapt to survive during this time period.

Today *C. nitida* and *C. storeyi* can be found within 5km of one another and seemingly share similar habitats, meaning that there is potential for the two species to interbreed where their geographic ranges meet. It is unclear, however, if their ancestors remained separated long enough that they are now reproductively isolated species that cannot produce fertile offspring if they breed.

Dr Nicole Gunter from the Queensland Museum and her associates recently analysed the DNA of both species of dung beetle and found that the differences in the species' DNA are minimal and below the genetic threshold used to normally differentiate species. They also used data available on the Atlas of Living Australia (ALA) to model their species distribution and examine environmental factors that predict their range. The models suggests that they gravitate to different environmental conditions.

You will be investigating potential causes for the divergence of *C. nitida* and *C. storeyi* using spatial distribution data available on the ALA Spatial Data Portal to test Dr Reid's hypothesis that these are two different species that were geographically isolated in the Pleistocene epoch due to changes in climate and habitat. You will then decide whether *C. nitida* and *C. storeyi* are one species or two. Although this lesson focusses on the biogeographic species concept, you will need to utilise all three species concepts to consider this question.

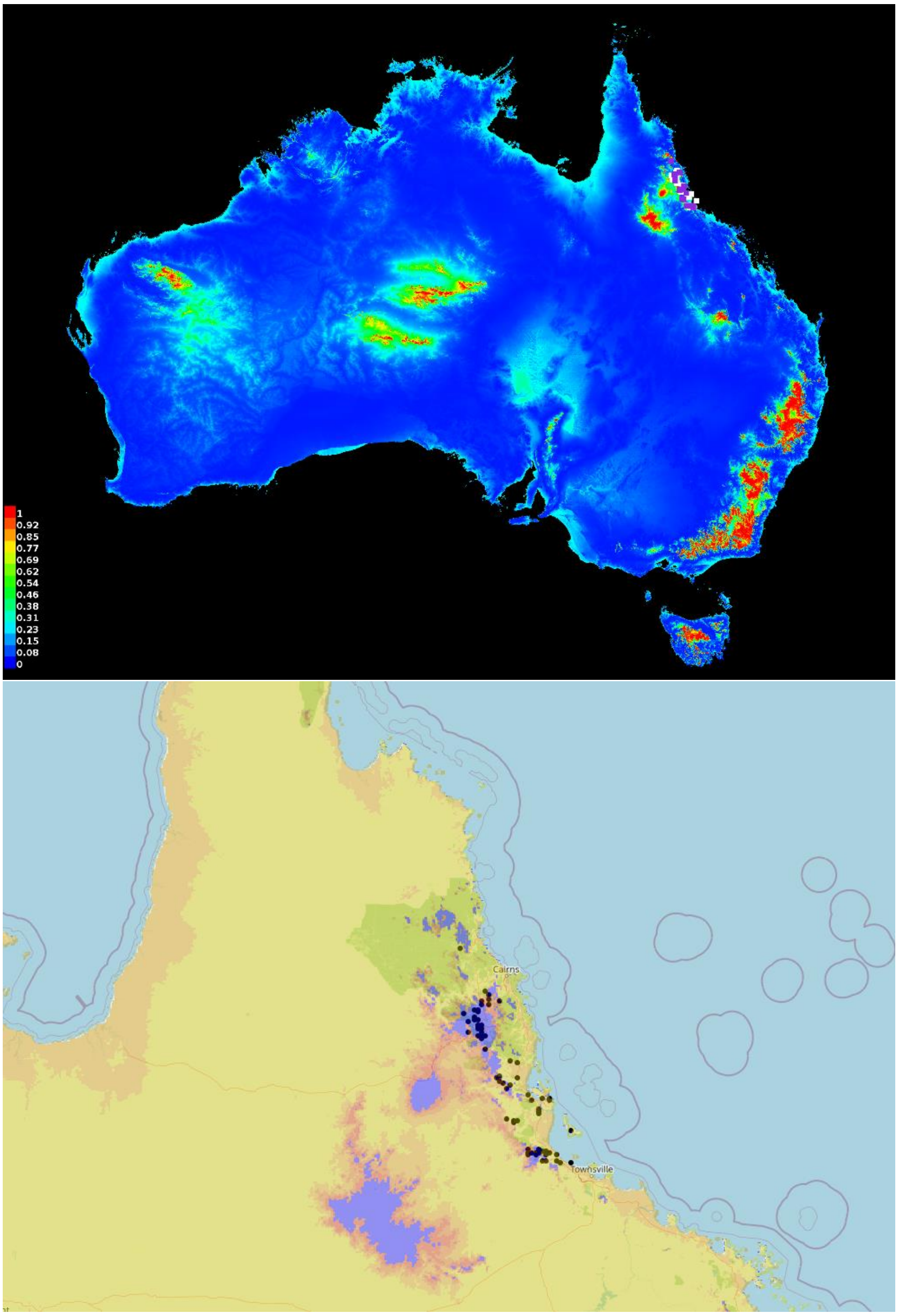
Follow the steps below to investigate the speciation of *Coptodactyla nitida* and *Coptodactyla storeyi.*

1. Access the Atlas of Living Australia Spatial Data Portal here: https://spatial.ala.org.au/. You will need to create an account to access this information.
2. Click 'Add occurrences to map' in the 'Quick Links' box at the bottom left-hand side of the page.
3. Type '*Coptodactyla storeyi*' into the 'Search for a species by scientific or common name' box and click 'Next>'.
    a. You will notice that a number of coloured dots begin to appear on the map of Australia near Cairns. These dots represent individual observations of the species by scientists and members of the public.
4. Click on 'Add occurrences to map' again and use the same search field to search for *Coptodactyla nitida*. You will notice that *C. storeyi's* records are just south of *C. nitida* with little to no overlap.
5. Click on 'Map Options' on the left-hand side of the screen and select 'Outline'. This will remove features from the map and show a basic outline of the Australian coast, reducing clutter. You may like to later apply the Satellite base map option to further explore the area.
6. Click on 'Add Layer to map'.
7. In the 'Filter Layers' box type 'Elevation' and check the box next to the layer that appears.
8. Click 'Next>'
9. Zoom in on Queensland to more clearly view the species' records.
10. You should now see a coloured layer showing the elevation in metres across all of Australia. Compare the spatial distribution records for the two species against the elevation layer.

Do you notice any features of the landscape that might explain why *C. nitida* and *C. storeyi* speciated? If not, why? (**Hint:** The information at the start of this lesson mentions geographic isolation caused by the Black Mountain barrier).

The Atlas of Living Australia Spatial Data Portal uses a machine learning algorithm called Maxent to generate predictions of suitable habitat. It does this by comparing spatial data records (such as those you generated for *C. nitida* and *C. storeyi*) to one or more spatial or climatic variables (such as temperature, rainfall, and elevation).

The map below was generated from Maxent to predict the habitat of *C. nitida* based on the elevation of locations at which *C. nitida* is currently known to live (current locations of *C. nitida* are shown as purple and white dots). We can get a much closer look at *C. nitida's* habitat by loading the same prediction into the spatial data portal as a layer and zooming in on Queensland. In the lower image, species locations are shown in black.



Predicted habitat for *C. nitida* based on elevation of currently known habitat. From Atlas of Living Australia – Spatial Data Portal

Do you think elevation is a good indicator of suitable habitat for C. *nitida*? Why/why not? Use evidence from the map to support your decision.

Read the information below describing the lifestyle of dung beetles, specifically from the genus Coptodactyla.

Dung Beetles

Dung beetles are part of the subfamily Scarabaeinae. Although most feed on dung, some feed on decaying plant or animal matter.

Dung beetles can be found on every continent (except Antarctica) and are critical to the environment as they recycle the nutrients found in dung back into the ecosystem. In this way, they are important decomposers in our environment.

Dung beetles are often categorised into 3 groups, based on the way in which they process dung: rollers, dwellers and tunnelers.

Many people are familiar with rolling dung beetles, which create balls of dung that they then roll away for feeding and breeding. The males sometimes use these dung balls as 'nuptial gifts' to court females.

Dwellers stay on top of the dung and lay their eggs on it. When the eggs hatch the larvae eat and grow inside the dung until they're ready to emerge.

Tunnelers dig tunnels underneath the dung and then transport bits of it into these tunnels. They also use this dung for food and reproduction.

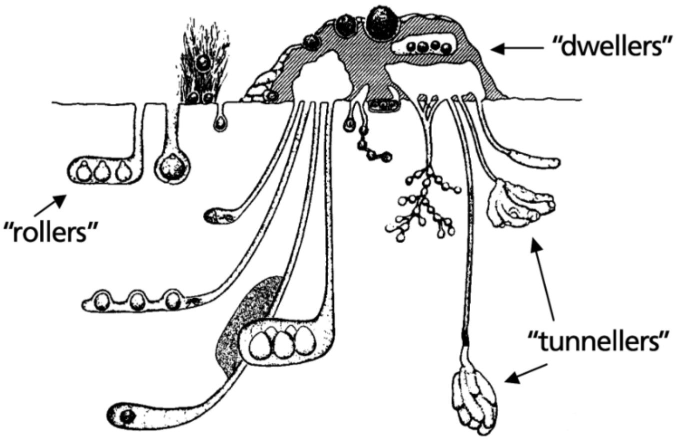


Diagram showing rolling, tunneling and dwelling nesting behaviours of dung beetles. From Floate K.D. (2011) "Arthropods in Cattle Dung on Canada's Grasslands" in Agriculture and Agrifood Canada.

Dung beetles from the genus *Coptodactyla* are tunnelers. Some of them have prominent horns, which are speculated to help the beetles defend their tunnels. *C. nitida* and *C. storeyi* do not possess horns, however, and are extremely similar to each another.

Dung beetles are reliant on local flora and vertebrate species for their food source. Because of this, areas that have been converted to farmland (for both crops and livestock) may cause a decline in local dung beetle populations due to land clearing and habitat fragmentation.

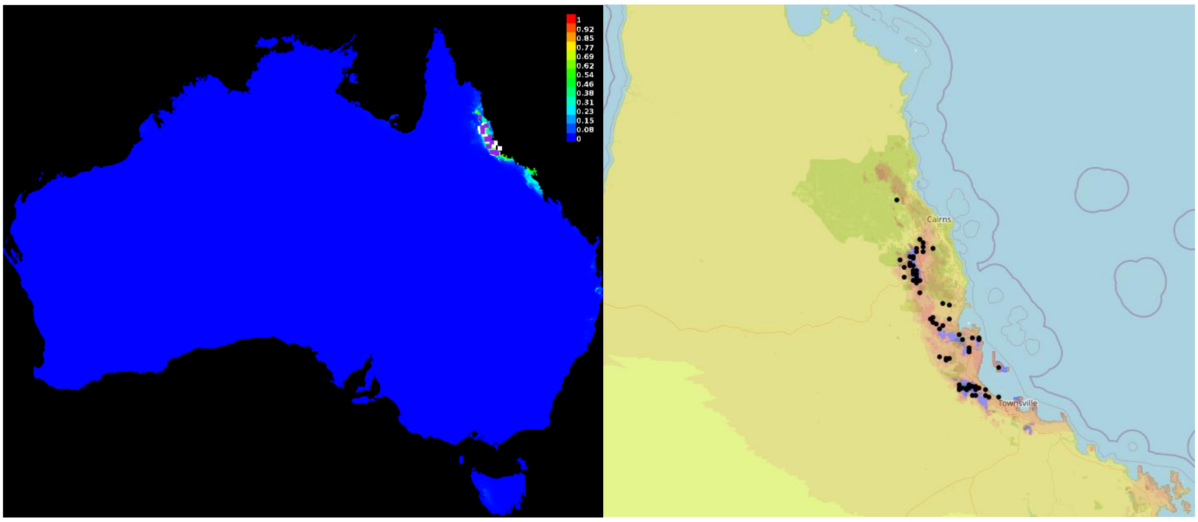
In Dr Christopher Reid's paper that describes *Coptodactyla* species, there are comments on the forests that species inhabit. *Coptodactyla storeyi* seems to prefer rainforest and *C. nitida* seems to prefer open eucalypt and casuarina forests. Using this information and your previously generated distribution data as a guide, propose some variables that might impact the habitat of *C. nitida* and *C. storeyi*.

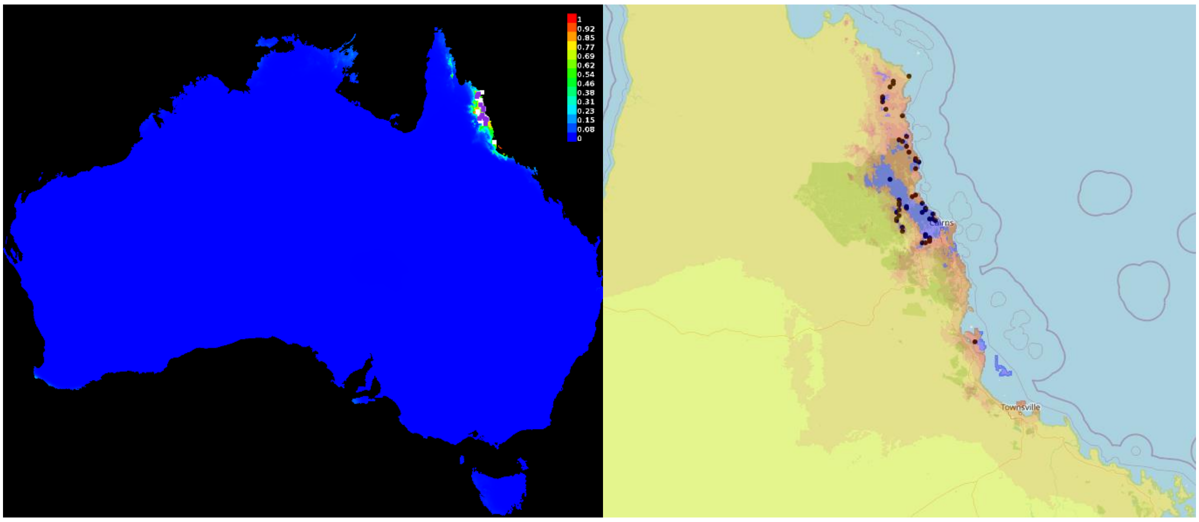
The table below shows the five most common bioclimatic factors used in Maxent's habitat predictions for *C. nitida and C. storeyi*. Each number is the percentage influence that the factor has on the generated prediction. The higher the number, the more influence that factor has.

Table 1. Percentage influence on Maxent habitat predictions. Factors contributing less than 10% are listed as '<10'.

	Temperature Seasonality	**Max Temperature of Warmest Month**	**Precipitation Seasonality**	**Precipitation of Wettest Quarter**	**Precipitation of Warmest Quarter**
C. nitida	26.9	<10	<10	<10	62.7
C. storeyi	15.5	15.3	17.1	14	18.1

The following maps were generated from Maxent to predict the habitat of C. *nitida* and C. *storeyi* based on the five most important climatic factors (see Table 1). On the maps on the right, blue indicates a high likelihood of a species occurring. Red, orange and yellow areas each have lower likelihood. Consider only the blue and dark red areas to be the likely distribution of the species. These areas have appropriate environmental conditions for the species to survive.





Predicted habitat for C *storeyi* based on the five most important factors (see Table 1). From Atlas of Living Australia – Spatial Data Portal

Based on these maps and table 1, do you think that C. *nitida* and C. *storeyi* should have greater overlap in their distribution? Why? Why not? Use evidence from the maps to support your ideas.

It should be quite clear that precipitation and temperature have a large impact on both species' distributions. Knowing that *C. storeyi* prefers rainforest habitat and *C. nitida* prefers open forest, what effect do you think precipitation and temperature would have on these habitats?

It has been proposed that *C. nitida* and *C. storeyi* diverged from one another due to a dry section of woodland that divided their rainforest habitat in the Pleistocene epoch.

Based on the map predictions you have seen in this lesson, evaluate this hypothesis. **Hint:** Think about what would have happened to precipitation and temperature in the area during this period.

Assuming the dry woodland that formed during the Pleistocene epoch does explain the divergence of *C. nitida* and *C. storeyi*, propose a reason that *C. nitida* and *C. storeyi* now seem to prefer different conditions. **Hint:** Consider natural selection in your answer.

So far, Maxent's predictions have assumed that *C. nitida* and *C. storeyi* are separate species. That is, the predictions were calculated with the species data already separated. Dr Gunter and her associates, however, recently used DNA barcoding to compare the differences between *C. nitida* and *C. storeyi* DNA. They found that there was approximately a 1% difference in the DNA barcode they used (Cytochrome Oxidase 1). This means that there are only minimal genetic differences between *C. nitida* and *C. storeyi* and calls their status as separate species into question.

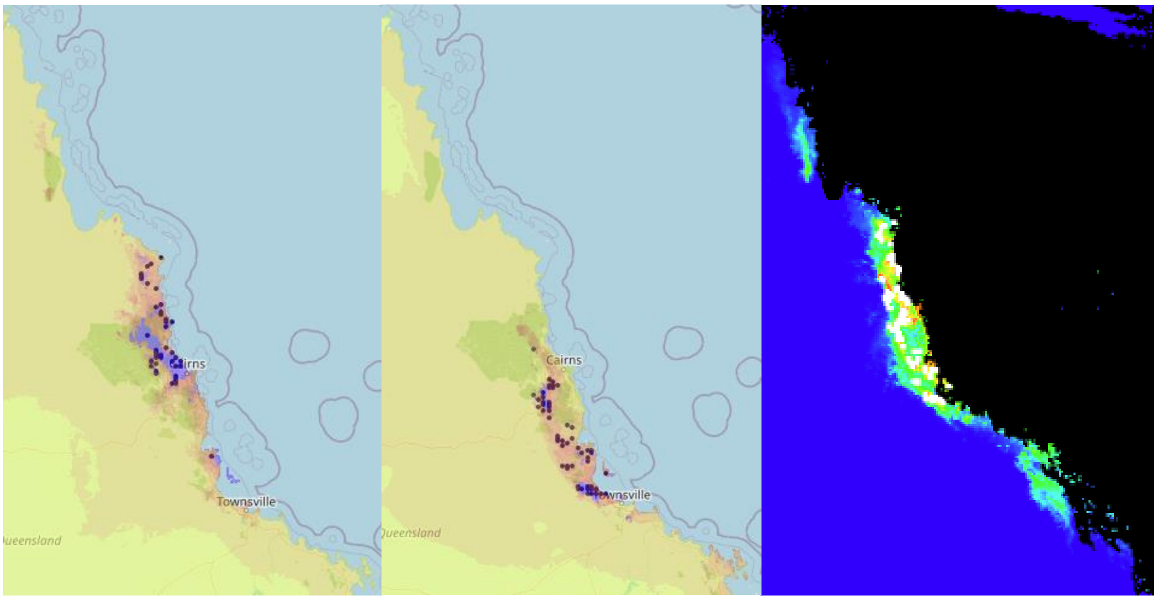
Table 2 below shows the five most common bioclimatic factors used in Maxent's habitat predictions for *C. nitida*, *C. storeyi* and both species combined (i.e. assuming they are the same species). Each number is the percentage influence that the factor has on the generated prediction.

Table 2. Percentage influence on Maxent habitat predictions (including for combined species data). Factors contributing less than 10% are listed as '<10'.

	Temperature Seasonality	**Max Temperature of Warmest Month**	**Precipitation Seasonality**	**Precipitation of Wettest Quarter**	**Precipitation of Warmest Quarter**
C. nitida	26.9	<10	<10	<10	62.7
C. storeyi	15.5	15.3	17.1	14	18.1
Combined	12.1	15.7	18.5	<10	41

The images below compare Maxent's habitat predictions for C. *nitida* and C. *storeyi* to its prediction for both species combined (i.e. as if they are one species). In the two predictions on the left, strong predictions of habitat are shown in blue (red and orange are weaker predictions, species observations are in black). The colours are reversed in the prediction on the right and strong predictions are shown in red/orange (green and light blue are weaker predictions, species observations are in white).

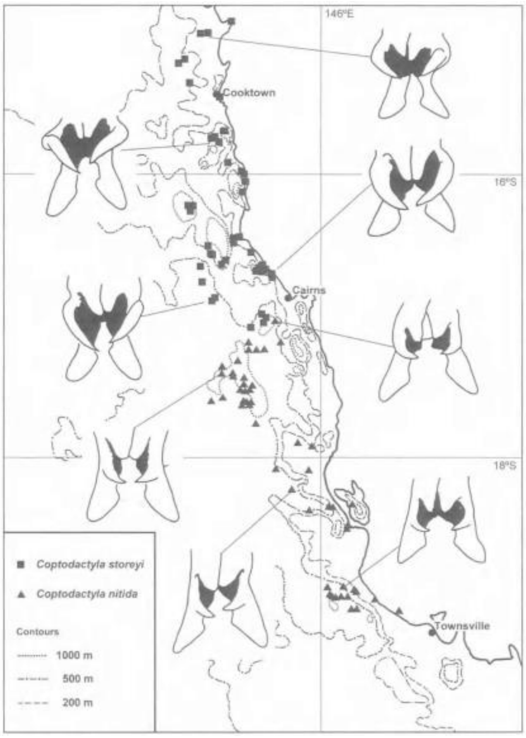
Note: The combined prediction was not generated in the spatial data portal as it does not allow species data to be combined. Instead, it was generated manually in Maxent, which is why it cannot be viewed as a layer in the data portal.



Predicted habitat for C *storeyi* (left), C. nitida (middle) and both species combined (right). based on the factors in Table 1. From Atlas of Living Australia – Spatial Data Portal

Does this evidence support Dr Reid's conclusion that C. *nitida* and C. *storeyi* are separate species? Why/why not?

The following image is from Dr Chrisopher Reid's 2000 paper in *Memoirs of the Queensland Museum*. It shows the shapes of the paramere apices (an internal morphological feature that is very important for defining beetle species). There are no external features that can be used to differentiate the species.



Map of North Queensland, showing distribution of *Coptodactyla nitida* and *Coptodactyla storeyi* with shape of paramere apices at various sites. From Reid C. (2000) "A Complex of Cryptic Species in the Genus Coptodactyla Burmeister (Coleoptera Scarabaeidae: Coprini)" in *Memoirs of the Queensland Museum*.

The information presented in this lesson so far is as follows:

1) The comparison you conducted of Maxent's habitat predictions for *C. storeyi, C. nitida* and both species combined **(bioclimatic).**
2) *C. nitida* and *C. storeyi* have only minimal genetic differences (approx. 1% difference in Cytochrome Oxidase 1) **(genetic).**
3) There are slight differences in the paramere apices between the two species, which align with the locations they are found in (above) **(morphological).**

Based on this information, do you think *Coptodactyla nitida* and *Coptodactyla storeyi* should be classified as one species or two? Use the evidence you have analysed during this lesson to support your decision. Ensure you link to the overarching theories of Natural Selection and Evolution.

How could you test your decision by gathering more data? What extra information would you need to check your decision and how could you get it?

Appendix

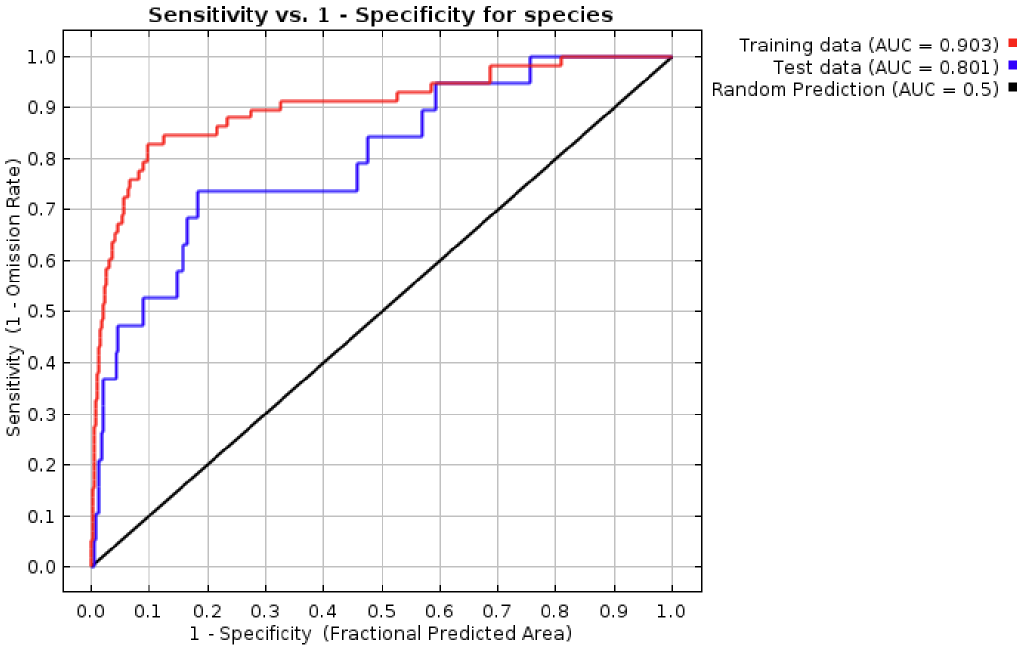
All of the maps used in this lesson (except for the final combined analysis) were generated using the ALA Spatial Data Portal. The ALA Spatial Data Portal contains a vast collection of data on a wide range of species. If you are particularly interested in learning more about a species, you can generate your own prediction maps by:

1. Clicking 'Add occurrences to map' and loading species occurrences for a species or group of your choice, as outlined in the lesson above.
2. Clicking 'Generate prediction for *species*'
3. Checking one or more boxes next to the 'layers' you wish to generate a prediction for.
4. Clicking 'Next >'
5. You can also refine your prediction further by adjusting some of the settings (e.g. area to restrict prediction) before pressing 'Next >' but this is not required.
6. Maxent can take a few minutes to generate your prediction, depending on the amount of data available. The final prediction that you receive will load in a new tab and also download to your device as a .zip file (for later use).

When your prediction is generated, you will notice that there is much more information available to you beyond just the type of maps you saw in this lesson. The majority of this information is beyond the scope of this lesson and has not been included accordingly, but it can be very helpful to gain a proper understanding of what your prediction actually means. A breakdown of the two graphs you will receive, Receiver Operating Characteristic and Analysis of Omission/Commission, has been included below to help your understanding.

The graphs on the next pages were generated from Maxent to predict the habitat of *C. nitida* based on elevation.

Receiver Operating Characteristic:



A Receiver Operating Characteristic (ROC) plots the rate of true positive results against the rate of false positive results. It is used as an indicator of how accurate a predictive model is as it shows how often the model correctly predicts a positive result versus how often it incorrectly predicts a positive result.

x-axis (1-Specificity (Fractional Predicted Area)): This is the rate of false positives or, how often Maxent incorrectly predicted areas were *C. nitida* is found. A 0.5 value for '1 – Specificity' means that 50% of Maxent's predictions of *C. nitida* habitat were incorrect.

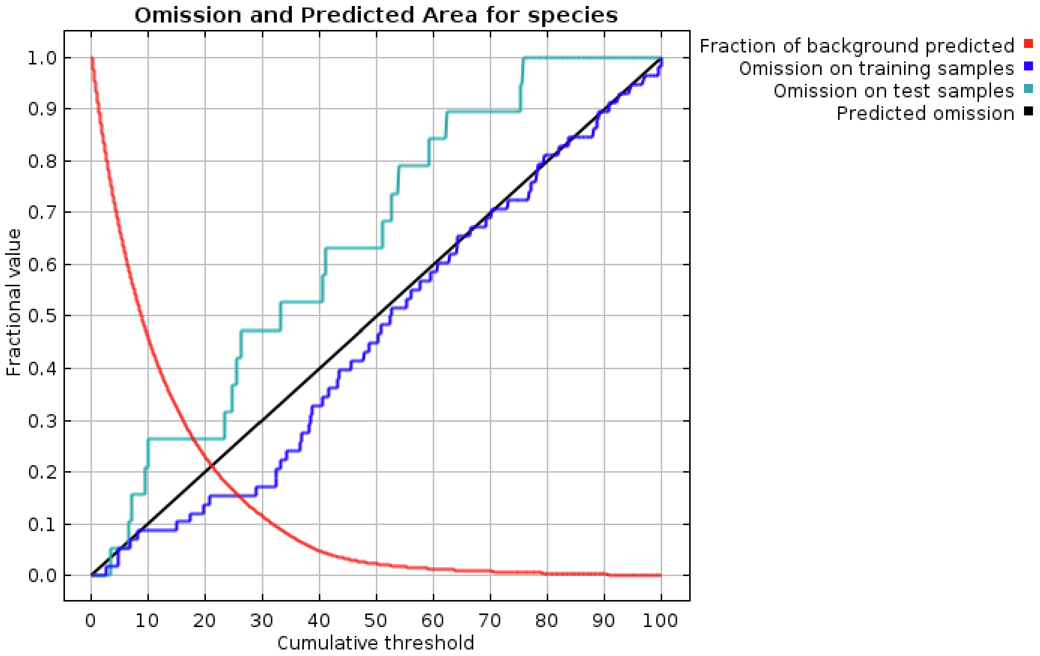
y-axis (Sensitivity (1 – Omission Rate)): This is the rate of true positives or, how often Maxent correctly predicted areas where *C. nitida* is found. A 0.5 value for 'Sensitivity' means that Maxent only predicted 50% of the locations correctly.

Training data (red line): Maxent trains itself on a sample of the data. This line is a representation of how accurate the model was during this training process.

Test data (blue line): This line is a representation of how accurate the model was after it was trained (i.e. performing a full test).

AUC: This stands for 'Area Under the Curve'. It is literally a calculation of the amount of area between a line and the x-axis. In a perfect model, the blue test line would go straight up (parallel with the y-axis) until it reaches 1.0 and then go straight to the right (parallel with the x-axis). In this 'perfect model' the AUC value would be 1 (or 100%). This would mean that, regardless of how many false positives the model returned, it also returned 100% of the true positives. If this occurred, the model would be correctly predicting all the suitable habitat for a species regardless of how often it also thinks unsuitable habitat is actually suitable.

Analysis of Omission/Commission:



An analysis of omission/commission plots the rate of false negatives against the rate of false positives. In essence, it shows the amount of area that was incorrectly predicted to contain a species against the amount of area that was incorrectly predicted to not contain a species.

Omission: False negatives or, in this case, areas in which a species does occur where it was not predicted to occur. Maxent has incorrectly predicted that the species does not occur in a part of Australia where it does occur.

Commission: False positives or, in this case, areas in which a species does not occur where it was predicted to occur. Maxent has incorrectly predicted that a species occurs in a part of Australia where it does not occur.

x-axis (cumulative threshold): Cumulative threshold refers to the threshold of omissions that Maxent expects will be present in its prediction. At a higher cumulative threshold Maxent predicts that it will miss more suitable areas of habitat. A cumulative threshold of 50 will result in 50% false negatives, which is why the predicted omission line (in black) is on a perfect 45-degree angle.

Fraction of background predicted (red): This line shows the fraction of all areas assessed (in this case all of Australia) that are predicted to contain a species. At a cumulative threshold of 0 (no false negatives), all areas containing the species are predicted to contain it since no areas were omitted. This doesn't mean that all areas were correctly predicted though, since there are probably plenty of areas on the map that *don't* contain the species that Maxent predicted *do* contain the species (false positive). Put simply, there is a trade-off between omission and commission: the higher the cumulative threshold (or predicted level of omission) is, the stricter the model is with its predictions and, as a result, the lower the rate of commission (or false positives).

In a perfect scenario the red line in this graph would drop off very suddenly and then stay low. This would mean that, even with a low rate of omission, Maxent also has a low rate of commission (resulting in an accurate prediction).

Omission on training samples (cyan): Maxent trains itself using a sample of the available data. If Maxent's prediction is 100% accurate this line should be on top of the black line.

Omission on test samples (blue): This line should also be close to the black line, using the same logic as the 'omission on training samples' line. If the training data has provided an inaccurate model, however, this line might be close to the black line because Maxent *thinks* it's accurate only because it was poorly trained.

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