Model design for ClimateWatch Species Distribution Models

The species' profiles on the ClimateWatch website include three maps for the current and future predicted habitat suitability and the change between the current and future predictions. These maps are based on species distribution models (SDMs). These models are developed with the use of a computer algorithm that predicts the habitat suitability for a given species based on the environmental conditions of the locations where we have already observed individuals of the species. These models are often used to help identify areas that should be prioritised for conservation, for example for endangered species, but can also be of value in evaluating the potential of an invasive species to settle in particular areas (Pearson 2010).

It is important to note that these maps do not show actual occurrences of a species, but highlight areas that have similar environmental conditions to areas where we have already found the species, and thus it is an estimation of where the habitat is suitable for a species to survive. This does not necessarily mean that a species actually exists in the area.

The models used for the maps in the ClimateWatch species profiles were run in the Biodiversity and Climate Change Virtual Laboratory (BCCVL, www.bccvl.org.au). This is a cloud-based online platform that integrates spatial modelling tools and datasets with high performance computers and major data storage facilities to investigate the impact of climate on the world's biodiversity (Hallgren et al. 2016). The virtual lab provides access to a suite of biological, environmental and climate data that users can easily visualise and use in biodiversity analysis. The BCCVL was used to provide baseline habitat suitability maps and climate change projections for each species. Below is an outline of the methods used for the analyses to generate these maps. Please note that these maps only provide a guidance of the habitat suitability for a species.

Input species data

Species distributions are modelled with occurrence data for each species. These are records with the coordinates of locations where a species has been observed. The Atlas of Living Australia (ALA, www.ala.org.au) is the national biodiversity database that hosts occurrence records for more than 100,000 species. Species observations from ClimateWatch are also added to the ALA database. As the ClimateWatch data alone might not cover the entire range of a species, it was decided for these models to supplement the ClimateWatch data with available data from ALA.

It is important to check the species occurrence data before it is used in a model and make sure that only relevant data is used. The ClimateWatch team cleaned the data for each species using the ALA Spatial Portal. Data points were excluded if:

- They had a coordinate uncertainty >1km. The climate and environmental data in the model have a ~1 km resolution, and therefore it was decided to only use occurrence data for which the location was recorded within a 1 km accuracy.
- They were recorded before 1976 to match the time frame of the current climate data.

- They were recorded in a location outside the known range of the species.

All occurrence records for each species were plotted on a map and visually inspected for any remaining outliers. Species experts were asked for a final check and advice on dubious records.

Input climate/environmental data
Environmental data describes the conditions of the locations where a species is observed. As such these are the predictor variables in a model. It was beyond the scope of this project to define a set of climate and environmental variables for each species separately, and thus a baseline model was run for groups of species with generic variables that impact habitat suitability for these groups. The environmental and climate variables used in these models were determined per group of species as follows:

<u>Plants</u>
Australia, Current Climate, ~1km resolution (Vanderwal 2012). Layers:
B01 (annual mean temperature), B04 (temperature seasonality), B05 (maximum temperature of warmest month), B06 (minimum temperature of coldest month), B12 (annual precipitation), B15 (precipitation seasonality), B16 (precipitation of wettest quarter), B17 (precipitation of driest quarter).

Australia, Substrate Fertility, ~1km resolution (CSIRO 2013). Layers:
Lithology fertility, Lithology mean age

National Soil Grids Australia, ~250m resolution (ACLEP 2012). Layers:
Clay content percentage (0-30 cm), Plant available water capacity (0-1 m)

<u>Birds / Mammals</u>
Australia, Current Climate, ~1km resolution. (Vanderwal 2012). Layers:
B01 (annual mean temperature), B04 (temperature seasonality), B05 (maximum temperature of warmest month), B06 (minimum temperature of coldest month), B12 (annual precipitation), B15 (precipitation seasonality), B16 (precipitation of wettest quarter), B17 (precipitation of driest quarter).

Australia, Dynamic Land Cover, ~250m resolution (Lymburner et al. 2011). Layers:
Land cover, recalculated by BCCVL in 5 classes.

<u>Reptiles / Spiders / Insects</u>
Australia, Current Climate, ~1km resolution. (Vanderwal 2012). Layers:
B01 (annual mean temperature), B04 (temperature seasonality), B05 (maximum temperature of warmest month), B06 (minimum temperature of coldest month), B12 (annual precipitation), B15 (precipitation seasonality), B16 (precipitation of wettest quarter), B17 (precipitation of driest quarter).

Australia, Dynamic Land Cover, ~250m resolution. (Lymburner et al. 2011). Layers:
Land cover, recalculated by BCCVL in 5 classes.

Australia, Substrate Fertility, ~1km resolution (CSIRO 2013). Layers:
Lithology fertility, Lithology mean age

Freshwater related species (frogs and turtles)
Australia, Freshwater Catchment Current Climate , ~250m resolution (Stein et al. 2014). Layers:
B01 (annual mean temperature), B05 (maximum temperature of warmest month), B06 (minimum temperature of coldest month), B12 (annual precipitation), B16 (precipitation of wettest quarter), B17 (precipitation of driest quarter).

Model settings
For each species, a Maxent model (Phillips and Dudík 2008) was run with default settings. The area used for generating the 10,000 background points was the convex hull (= minimum polygon) around all occurrence records for the species with an additional 200 km offset.

Future climate data
The future potential habitat suitability was modelled for each species for the year 2070 for a Representative Concentration Pathway (RCP) of 8.5. RCPs define a specific trajectory with projected outcomes in the year 2100 for how much the planet has heated up, and the concentration of greenhouse gases. RCP8.5 represents a business-as-usual scenario that incorporates little action to reduce carbon emissions, a continued growth of the world population to about 12 billion by 2100, heavy use of fossil fuels, and a continued increase in the amount of land used for cropland and grassland (Van Vuuren et al. 2011).

Due to the variation and differences in uncertainty among future climate projections, it is advised to use the average of multiple climate simulations rather than to project the species distribution models onto a single future scenario (Beaumont et al. 2008). Therefore each species distribution model was projected using 7 different general circulation models (GCM) as recommended by the CSIRO (CSIRO 2015): ACCESS1.0, CESM1-CAM5, GFDL-ESM2M, HadGEM2-CC, CanESM2, MIROC5, and NorESM1-M. The predicted habitat suitabilities of these 7 future climate projections were then averaged to create the map for the 2070 potential habitat suitability.

Based on the current predicted habitat suitability and the averaged projection for 2070, the BCCVL provides a range change map which indicates areas where suitable habitat might disappear or expand as well as areas where the habitat is predicted to be suitable for the species now and in the future.

References
ACLEP (2012) National soil data provided by the Australian Collaborative Land Evaluation Program ACLEP, endorsed through the National Committee on Soil and Terrain NCST. (http://www.asris.csiro.au/themes/NationalGrids.html).

Beaumont, LJ, Hughes L, Pitman AJ (2008) Why is the choice of future climate scenarios for species distribution modelling important? *Ecology letters* 11: 1135-1146. https://doi.org/10.1111/j.1461-0248.2008.01231.x

CSIRO (2015) Climate change in Australia - Technical Report. https://www.climatechangeinaustralia.gov.au/media/ccia/2.1.6/cms_page_media/168/CCIA_2015_NRM_TechnicalReport_WEB.pdf

CSIRO; Williams, Kristen; Wilson, Peter; Viscarra Rossel, Raphael; Gallant, John; Austin, Jenet; Dowling, Trevor; Wilford, John; Chen, Charlie; McKenzie, Neil; De Vries, Robert; Jacquier, David; Storey, Randal (2013): 9 second substrate rasters for continental modelling of Australia's biodiversity patterns. v2. CSIRO. Data Collection. https://doi.org/10.25919/5bd6780e2fbc6

Hallgren W, Beaumont L, Bowness A, Chambers L, Graham E, Holewa H, Laffan S, Mackey B, Nix H, Price J, Vanderwal J (2016) The biodiversity and climate change virtual laboratory: where ecology meets big data. *Environmental Modelling & Software* 76: 182-186. https://doi.org/10.1016/j.envsoft.2015.10.025

Lymburner L, Tan P, Mueller N, Thackway R, Lewis A, Thankappan M, Randall L, Islam A, Senarath U (2011) The National Dynamic Land Cover Dataset (v1.0), Geoscience Australia, Canberra. https://d28rz98at9flks.cloudfront.net/71069/Rec2011_031.pdf

Pearson RG (2010) Species' distribution modeling for conservation educators and practitioners. *Lessons in conservation* 3: 54-89. https://pdfs.semanticscholar.org/66db/947ee1a6ab91c408f489d17cfb6e068931a6.pdf

Phillips SJ, Dudík M (2008) Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. *Ecography* 31(2): 161-175. https://doi.org/10.1111/j.0906-7590.2008.5203.x

Stein JL, Hutchinson MF, Stein JA (2014) A new stream and nested catchment framework for Australia. *Hydrology and Earth System Sciences* 18: 1917-1933. https://doi.org/10.5194/hess-18-1917-2014

Vanderwal J (2012) All future climate layers for Australia - 5km resolution. James Cook University. https://researchdata.ands.org.au/future-climate-layers-5km-resolution/10856

Van Vuuren DP, Edmonds J, Kainuma M, Riahi K, Thomson A, Hibbard K, Hurtt GC, Kram T, Krey V, Lamarque JF, Masui T (2011) The representative concentration pathways: an overview. *Climatic change* 109: 5-31. https://doi.org/10.1007/s10584-011-0148-z