Australian Government
Department of the Environment, Water, Heritage and the Arts

Marine and Tropical Sciences Research Facility Milestone Report, November 2009

Program 5ii: **Climate Change: Rainforests and Catchments**

Project 2.5ii.4: Impacts of climate change on biodiversity

Project Leader: **Associate Professor Steve Williams, James Cook University (JCU)**

Summary

This project continues to remain on track and is progressing well. In this report, we provide current species distribution maps for rainforest fauna and maps of spatial patterns of biodiversity to eAtlas and Wet Tropics Management Authority.

We complete a case study testing the ability of species distribution models calibrated in the Wet Tropics to predict suitable environments further north on Cape York Peninsula. We find a moderate level of transferability for the most models generated for test species, and that simple models (in terms of number of parameters and complexity of functions) are generally more transferable than complex models. The result supports the idea that species' distribution models have the capacity to provide meaningful predictions of species' distributions under future climate change.

We use predictive impact modelling of climate change on rainforest fauna to model distributions of 202 rainforest vertebrates and project these onto climate surfaces representing 7 global climate models.

We report on current results on physiological tolerances of microhylid frogs and arboreal mammals. We document early maximum, minimum and preferred temperatures of microhylids, as well as other physiological parameters, that play a role in determining distribution. We find a pattern of response to high ambient temperature in arboreal mammals that is rapid and linear meaning these species will be significantly impacted by climate change.

The next milestones report will be a complete summary of all findings for objects stated under this project 2.5ii.4.

Project Results

Description of the results achieved for this milestone

1. Current species distribution maps for rainforest fauna finalised and provided to the e-Atlas (MTSRF Project 1.1.5), the coordinator of the status and trends project (MTSRF Project 1.2.1) and the Wet Tropics Management Authority (Objective B)

Maps of current species distributions have been created. Distributions were established using known occurrences of the species, the presence-only species distribution model *Maxent* (Phillips *et al.* 2006) and environmental layers representing long-term climate and vegetation. The modelled distributions of the 202 rainforest vertebrates were verified by experts (Stephen Williams, Yvette Williams, Luke Shoo, Craig Moritz and Collin Storlie). They were then clipped from a potential distribution (based on suitable environment) to a realistic distribution (distribution limited by dispersal abilities, biotic interactions, etc.) using ecologically-significant biogeographic boundaries; this was done by the same experts.

All distributions (potential and realised) have been provided to the e-Atlas, Petina Pert (for integration into MTSRF Project 1.2.1) and the Wet Tropics Management Authority. Provision of the data has been in the form of GIS layers and .jpg images with appropriate metadata.

Furthermore, all distributions, life history and phylogenetic data have been accepted for publication in Ecology (Williams *et al.* 2009).

References:

Phillips, S.J., Anderson, R.P. and Schapire, R.E. (2006). Maximum entropy modelling of species geographic distributions. *Ecol Model* 190: 231-259.

Williams, S.E., VanDerWal, J., Isaac, J., Shoo, L., Storlie, C., Fox, S., Bolitho, E.E., Moritz, C., Hoskin, C. and Williams, Y.M. (In Press). Distributions, life history characteristics, ecological specialisation and phylogeny of the rainforest vertebrates in the Australian Wet Tropics bioregion. *Ecology*.

2. Current maps of spatial patterns of biodiversity finalised and provided to the e-Atlas, the coordinator of the status and trends project and the Wet Tropics Management Authority (Objective B)

Maps of current spatial patterns of biodiversity have not yet been finalised nor provided to anyone. The problem is in the definition of biodiversity and the differing needs of groups accessing these maps. Each group is interested in spatial richness patterns of different taxonomic groupings of species; such groupings include biodiversity patterns for all species, birds, mammals, amphibians, microhylids, reptiles, etc. Further requests have been for endemic species only or rainforest obligates only for each of the above groups. By provision of the individual distribution maps, individual groups can assess the spatial patterns of biodiversity for any subset of the species they wish or we can produce them upon request.

3. Completion of case study testing the ability of species distribution models calibrated in the Wet Tropics to predict suitable environments further north on Cape York Peninsula (Objective B, F)

We used a ‘space-for-time’ approach to test whether climate change impact models that successfully predict current species’ distributions will provide meaningful predictions of species’ distributions under future climate change? We had two main objectives: (1) to use distribution models built on Wet Tropics data to predict the distribution of rainforest birds in warmer, lower latitude rainforests on Cape York Peninsula; and (2) to evaluate model precision and transferability. We report on each of these objectives in turn.

We generated six models for each of nine rainforest birds shared between Cape York Peninsula and the Wet Tropics that had sufficient data for analysis. The six models consisted of three different levels of feature complexity (functions for fitting model to data) and two levels of input environmental variables (number of climate parameters). This was done because we wanted to generate an understanding of how internal model characteristics might affect model transferability.

We find a moderate level of transferability for most models generated for test species (mean AUC = 0.70, n = 9). The result supports the idea that species’ distribution models have the capacity to provide meaningful predictions of species’ distributions under future climate change. The best performing model was for the Lewin’s Honeyeater *Meliphaga lewinii* (AUC = 0.98) and the worst was for the Rose-crowned Fruit-Dove *Ptilinopus regina* (AUC = 0.58). Secondary to this, we find that simple models (in terms of number of parameters and complexity of functions) are generally more transferable than complex models. This is despite the fact that complex models consistently yield better performance statistics for the calibration region (i.e. the Wet Tropics). This has important implications for impact prediction studies where performance statistics, typically only quantified in the calibration region, are used to infer model quality. We suggest that the low transferability of many complex models is a consequence of over-fitting the data.

We are now using this information to guide species distribution models in the prediction of future climate change impacts. Specifically we are restricting the complexity of models to yield more realistic test statistics and predictions that are likely to be more transferable in time and space.

Details of publications that have followed from the project:

The first manuscript arising from the project has already been accepted for publication. A second incidental natural history note has also been forthcoming and is currently in review. Results from the more comprehensive analysis of all bird data have been presented in the School of Marine and Tropical Biology Seminar Series, and again to the MTSRF. The corresponding manuscript is currently in preparation.

Journal articles (published or in review):

1. **Shoo, L.P**., Anderson, A., Williams, S.E. (Accepted) On the isolated Lewin’s Honeyeater population (*Meliphaga lewinii amphochlora*) from the McIlwraith Range uplands, Cape York Peninsula, Australia: Estimates of population size and distribution. *EMU-Austral Ornithology* (Accepted 4/9/09).

2. Anderson, A., Monasterio Martin, C. and **Shoo, L.P.** (In review) Breeding behaviour of the poorly known Australian hylid frog *Litoria longirostris*. *Herpetofauna*.

Conference presentations (speaker in bold):

2008: **Shoo, L.P.**, Anderson, A., VanDerWal, J. and Williams, S.E. (2008) *Finding rainforest birds with a thermometer and rain gauge.* School of Marine and Tropical Biology Seminar Series, James Cook University, Townsville.

2008: **Shoo, L.P.**, Anderson, A. and Williams, S.E (2008) *Can we really predict how species will respond to contemporary climate warming? Finding rainforest birds with a thermometer and rain gauge.* 2008 MTSRF Annual Conference, Cairns [Download proceedings]

4. Progress and status report on predictive impact modelling of climate change on rainforest fauna (Objective F)

Potential distributions of 202 rainforest vertebrates have been created. Current distributions were modelled; these models were projected onto climate surfaces representing seven global climate models (GCM) for which the predicted change in climate was per degree of global warming. The model predictions were for each of the seven GCMs for each degree of global warming from current to six degrees at 0.5 degree intervals. Future climate scenarios were provided by Suppiah Ramasamy and Jim Ricketts through MTSRF Project 2.5ii.1 and *OzClim* (www.csiro.au/ozclim).

Distributions representing robust, probabilistic predictions of each species for each change in global warming have been created. The probabilistic predictions represent the mean prediction (and variance) of the seven GCMs. These predictions are currently being validated/assessed by the expert opinion of Stephen Williams, Yvette Williams, Luke Shoo, Craig Moritz and Collin Storlie prior to further analysis / provision to others.

5. Preliminary results on physiological tolerances of microhylid frogs (Objective G)

The Environmental Protection Agency permit (No. WITK054668508) to carry out the physiology experiments was issued on November 2008.

The physiological parameters that have been gathered for each species are:

a) Maximum temperature tolerance;
b) Minimum temperature tolerance;
c) Preferred temperature;
d) Dehydration rate under exposure to dry air at 20°C; and
e) Metabolic rate based on O_2 consumption and CO_2 production under exposure to dry air at 20°C.

To collect the maximum and minimum tolerance temperatures the frogs were set into a cylindrical chamber in a water bath to increase or decrease the temperature. The maximum and minimum temperature at which the frog could not respond to a stimulus was recorded. The stimulus is slow rotation of the chamber, which is accompanied by recovery of the frog's normal posture.

The preferred temperature has been measured using a thermal gradient (from 7-40°C) that allows the frogs to move freely and choose their own temperature. A digital image is recorded of the frog's position within the gradient each minute over the two-hour measurement period, and temperature is recorded continuously at 100 mm intervals along the gradient, allowing a temperature to be interpolated for each position along the gradient.

Water loss rates have been collected using flow-through respirometry, providing a temperature and humidity-controlled air flow over the frog and analysing the air stream for flow-rate, O_2, CO_2 and water vapour. This allows calculation of metabolic rate, and instantaneous water loss rates. The overall water loss can be calculated by comparing the initial and final weight of the frog.

To date, four localities have been visited and between seven and eight species of Microhylid frogs (genus *Cophixalus*) have been surveyed. Seventy-three individuals have been tested in at least one experiment to get any of the parameters.

In the case of the Carbine Uplands locality, three species of *Cophixalus* occur at the study areas and since most of them have not been found calling (this is the only reliable non-molecular identifying characteristic), DNA samples must be used to identify their species. This is underway. Preliminary examination of the data suggest some physiological variation between species, but given that the sample sizes are low and species ID unclear until the molecular identification is complete, it is premature to supply them here.

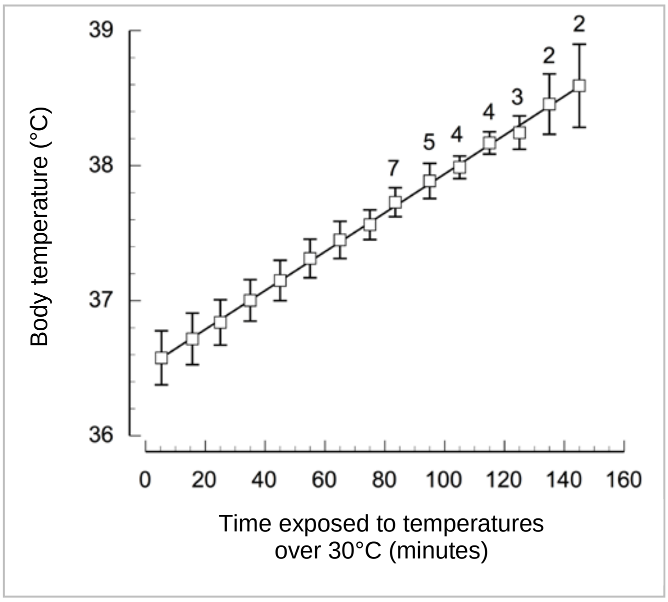
Field collection of the physiological measurements is continuing this wet season.

6. Report on physiological tolerances of arboreal mammals (Objective G)

This sub-project/objective was focused on determining the responses of Herbert River ringtail possums (*Pseudochirulus herbertensis*) and Lemuroid ringtail possums (*Hemibelideus lemuroides*) to elevated temperatures, for comparison with previous data for green ringtail possums (*Pseudochirops archeri*).

The pattern of response to high ambient temperature in green ringtail possums was a rapid and linear rise in body temperature dependent on the time they were exposed to ambient temperatures greater than 30°C (Figure 1). Krockenberger and Kanowski (in review) interpreted this pattern as a water conservation strategy, allowing body temperature to rise, thus storing excess heat for a period rather than utilising scarce water (scarce during the dry season due to limits on foliage intake imposed by plant toxins) for evaporative cooling. The excess heat can then be shed without recourse to evaporative cooling later in the evening when ambient temperatures fall. Given the rate of body temperature rise under these conditions in green ringtail possums, this strategy relies on ambient temperatures rising above 30°C for no more than about four hours per day, a limit that corresponds well with the rapid decline in possum density at sites where the average maximum temperature of the warmest week of the year is above 30°C.

Figure 1: Response of green ringtail possums to high ambient temperatures, showing elevation of body temperature at ambient temperatures greater than 30°C (from Krockenberger and Kanowski, in review).



We have now measured responses to changing ambient temperatures in eight Lemuroid and six Herbert River ringtail possums (final data collection for two further Herbert River ringtails is currently underway), and have a preliminary analysis of the response of the Lemuroid possums to changing ambient temperatures.

There was a similar pattern of response in body temperature as ambient temperature rises in the Lemuroid ringtails to that observed in the green ringtails, where body temperature rose linearly at temperatures over some threshold temperature (Figure 2). In contrast with the pattern in green ringtail possums, the threshold temperature at which Lemuroids allowed their body temperature to start rising was 28.5°C, and the rate at which body temperature rose was about 25% faster. This corresponds well with their elevated altitudinal lower-limit, above about seven hundred metres, compared with around four hundred metres in the green ringtail possum. This similarity in pattern gives us confidence that the same mechanisms are relevant for each of the ringtail possums, and the variation in the rate of temperature rise and threshold temperature between the species matches well with our expectations based on the differences in their altitudinal ranges, suggesting that Lemuroid possums are also likely to be limited by temperature extremes and negatively impacted by increases in the frequency and severity of those extremes as predicted under most climate change scenarios. This also gives us confidence that the mechanism proposed by Krockenberger and Kanowski (in review), that distribution of green ringtail possums is limited by an interaction between limitations on water intake imposed by plant defensive compounds and the requirements for evaporative cooling imposed by environmental extremes, has more general applicability to rainforest ringtails and may well provide a general mechanism for understanding limitations of the distributions of all marsupial folivores.

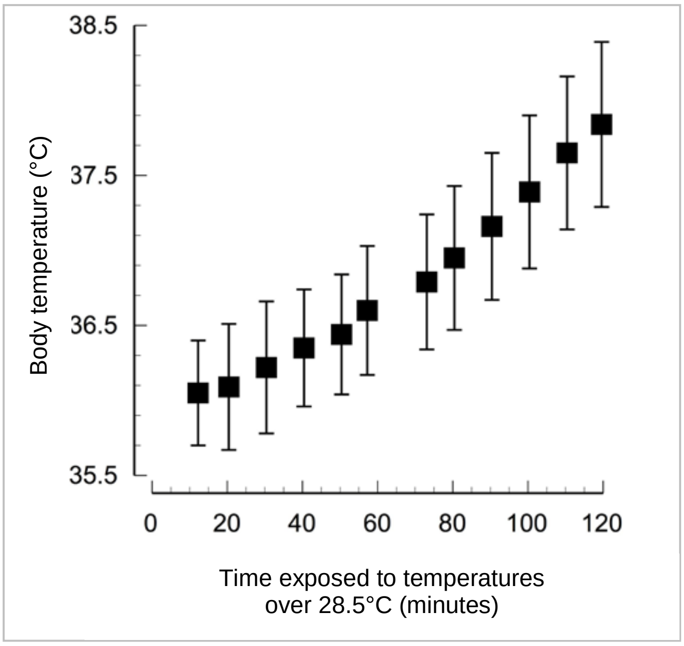


Figure 2: Response of Lemuroid ringtail possums to high ambient temperatures, showing elevation of body temperature at ambient temperatures greater than 28.5°C.

Communication, major activities and events

This milestone reporting period

Steve Williams, Jeremy VanDerWal, Luke Shoo, Andres Merino-Viteri and Brook Bateman all presented recent research findings from MTSRF-funded projects at the 10th International Congress of Ecology (INTECOL) in Brisbane (August 2009). This included oral presentations in two key symposia: *Amphibian Responses to Climate Change* and *Protecting Biodiversity: Adapting to Global Climate Change*.

Williams, S. E. (2009) *The role of protected areas in the face of climate driven extinctions in the Wet Tropics*. INTECOL 10th International Congress of Ecology, Brisbane, 16-21 August.

Moritz, C., Graham, C., VanDerWal, J. and Williams, S. E. (2009) *Effects of quaternary climate change increases sensitivity of montane tropical diversity to future global warming*. INTECOL 10th International Congress of Ecology, Brisbane, 16-21 August.

VanDerWal, J., Graham, C., Phillips, S., Beaumont, L., Moritz, C. and Williams, S. E. (2009) *The shifting refugia: Tracking spatial shifts in habitat through time to better understand refugia*. INTECOL 10th International Congress of Ecology, Brisbane, 16-21 August.

Williams, S. E., Shoo, L., VanDerWal, J., Isaac, J. and Williams, Y. (2009) *Protecting biodiversity: Adapting to global climate change*. INTECOL 10th International Congress of Ecology, Brisbane, 16-21 August.

Shoo, L., Storlie, C., VanDerWal, J. and Williams, S. E. (2009) *In search of cool refugia in a warming world.* INTECOL 10th International Congress of Ecology, Brisbane, 16-21 August.

Merino-Viteri, A., Shoo, L., Williams, S. E. and Krockenberger, A. (2009) *Can buffered conditions in refuges lessen effects of climate change impacts on Microhylid frogs?* INTECOL 10th International Congress of Ecology, Brisbane, 16-21 August.

Bateman, B., VanDerWal, J. and Johnson, C. (2009) *Modelling biotic interactions under climate change scenarios: Predicting Northern Bettong* (*Bettongia tropica*) *distribution*. INTECOL 10th International Congress of Ecology, Brisbane, 16-21 August.

Steve Williams, Luke Shoo and Andres Merino-Viteri also participated in an International workshop titled *Amphibian Response to Climate Change* that followed immediately after the INTECOL conference. The workshop gathered leading scientists from within Australia and internationally to discuss issues relating to amphibian conservation in the face of climate change.

Steve Williams was invited as a keynote speaker at the Southeast Asian Gateway Evolution (SAGE) conference in London in September.

Williams, S. E. (2009) *An integrated framework for assessing the vulnerability of biodiversity to climate change: Prioritising research and adaptation strategies*. Southeast Asian Gateway Evolution (SAGE) Conference, London, 14-17 September.

Planned for next milestone reporting period

Steve Williams will host and present recent research findings from MTSRF-funded projects in an NCCARF Terrestrial Biodiversity workshop on *Dynamic Conservation Planning* on 9-13 November.

Steve Williams will present MTSRF-funded research results at a workshop and meeting at The University of California - Berkeley in December.