Population modelling issues in predicting the effects of climate-change

- *a quick comparison of approaches*

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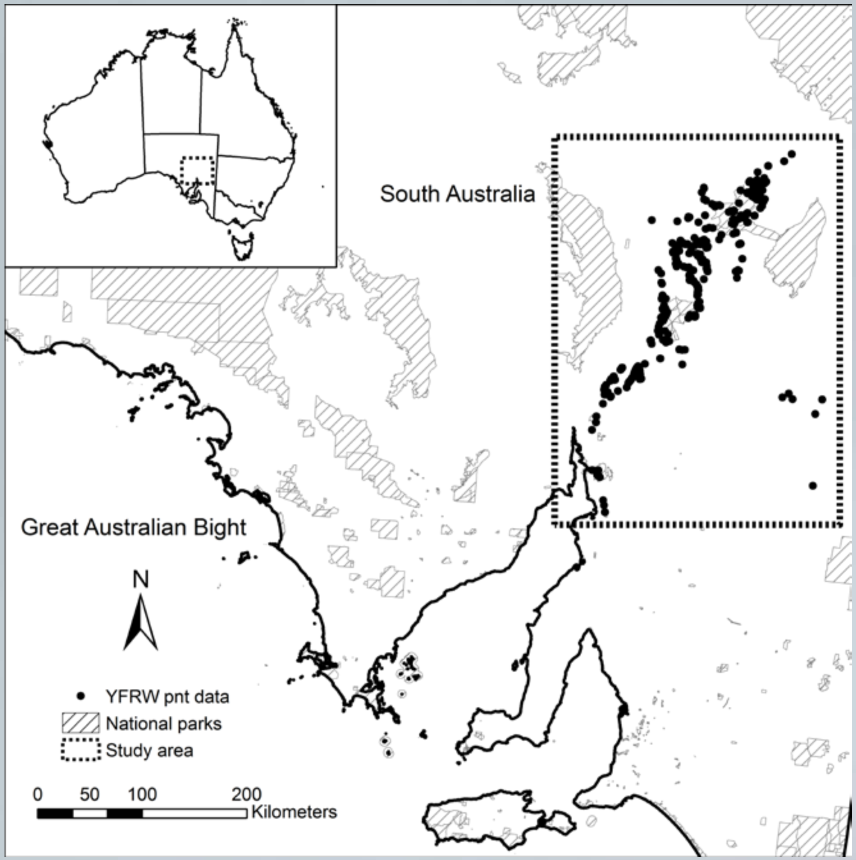
1. Population Viability Analysis



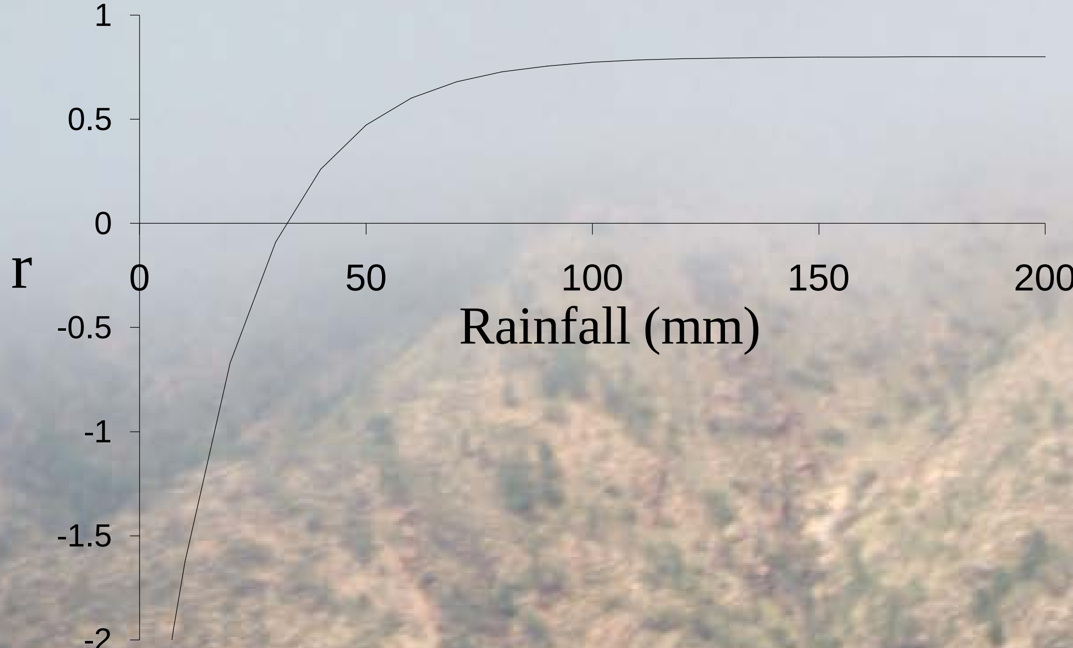
P. x. xanthopus

Rainfall and population response

N_t is the abundance at time *t* and N_{t-1} is the abundance at time *t* + 1.

$$r = \ln\left(\frac{N_{t+1}}{N_t}\right)$$

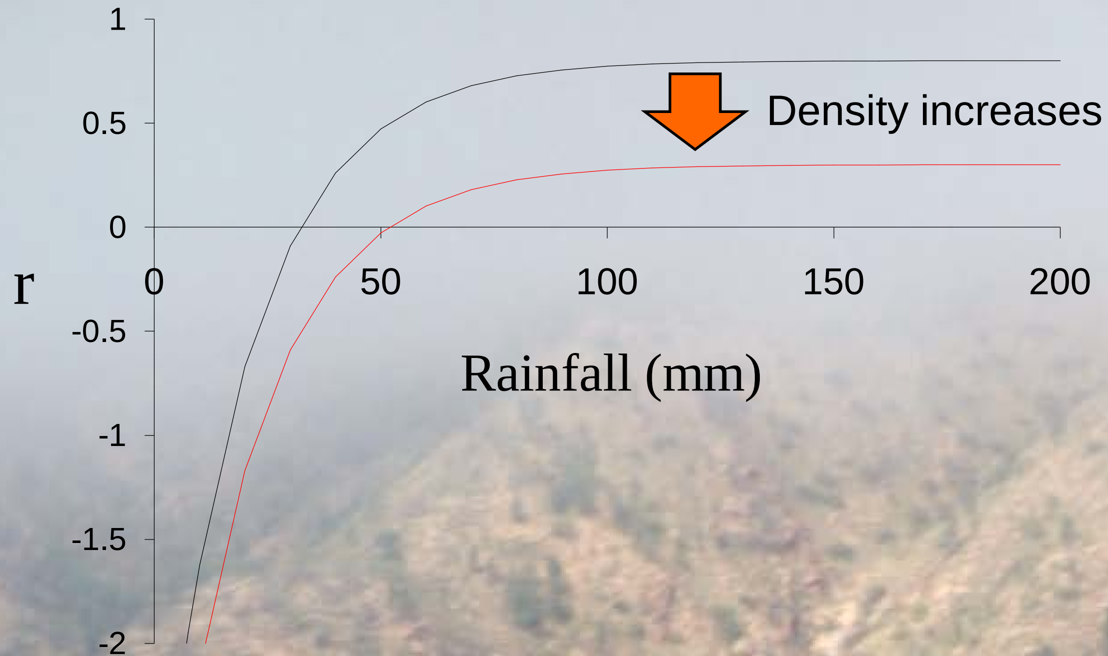
$$r = -a + c(1 - e^{-dv})$$



Response to rainfall and population density

Negative effects of density – intrinsic population regulation

$$r = -a + c(1 - e^{-dv}) - gD$$



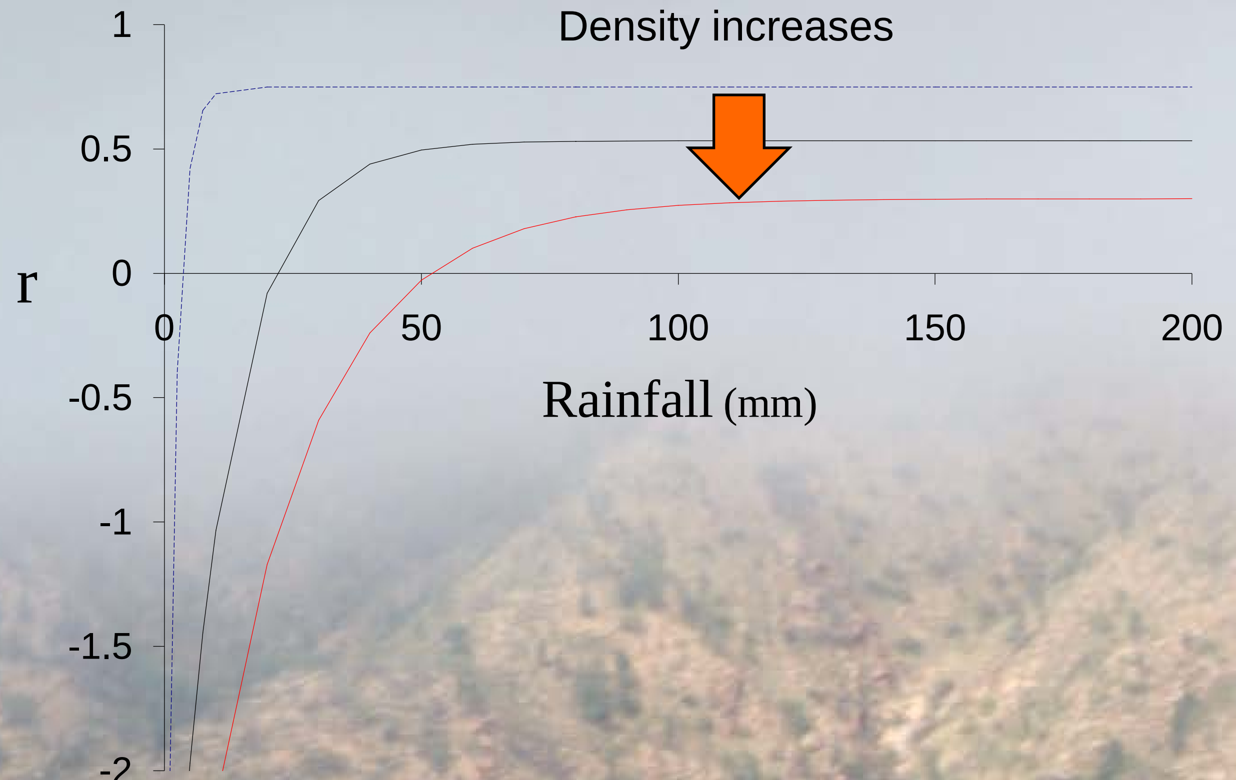
Response to rainfall and population density

However, the shape of response of rainfall may change with density-dependence

$$r = -a + c(1 - De^{-dv}) - gD$$

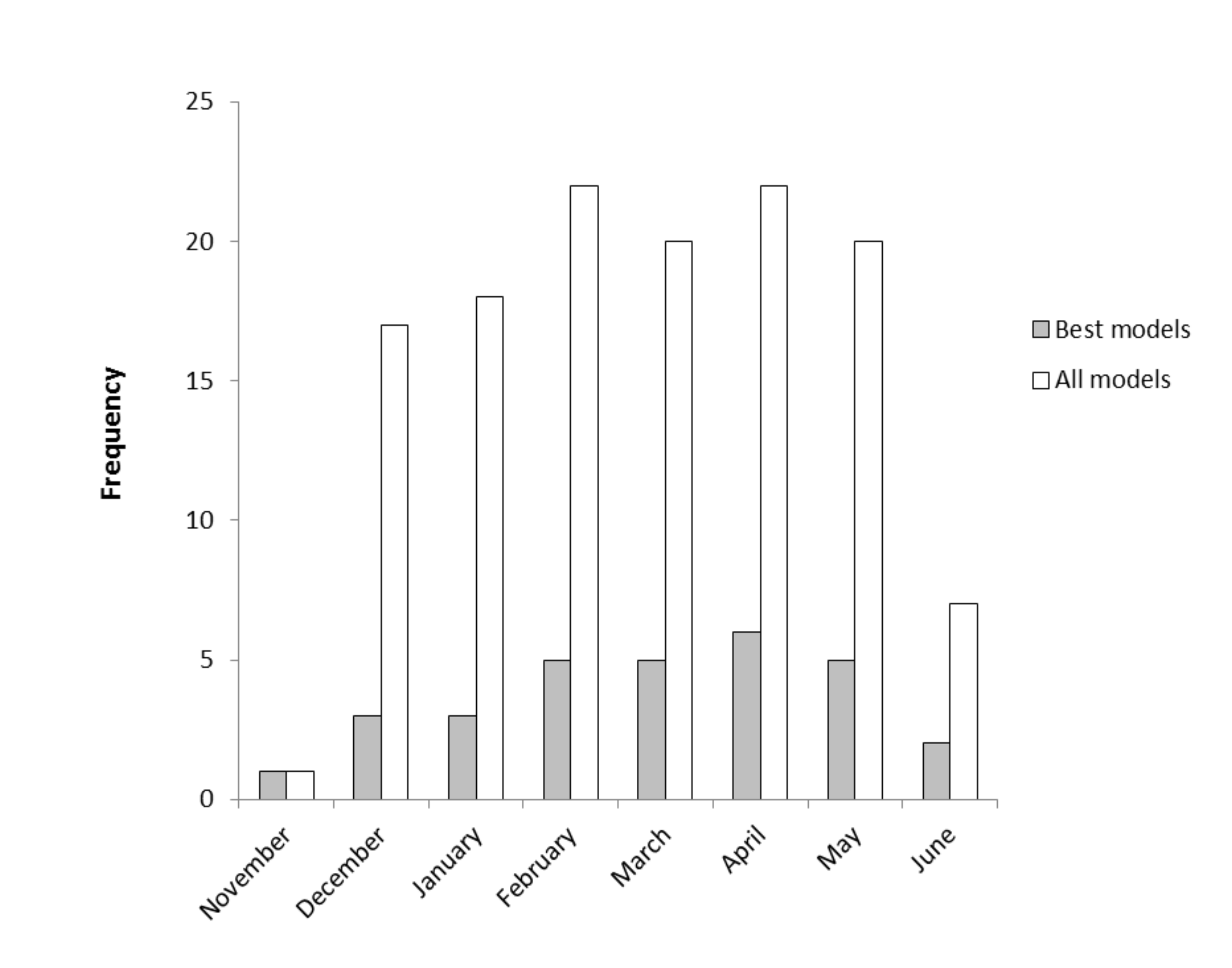
or

$$r = -a + c(1 - e^{-dv/D}) - gD$$



Rainfall period most affecting population growth rate of *P. x. xanthopus*

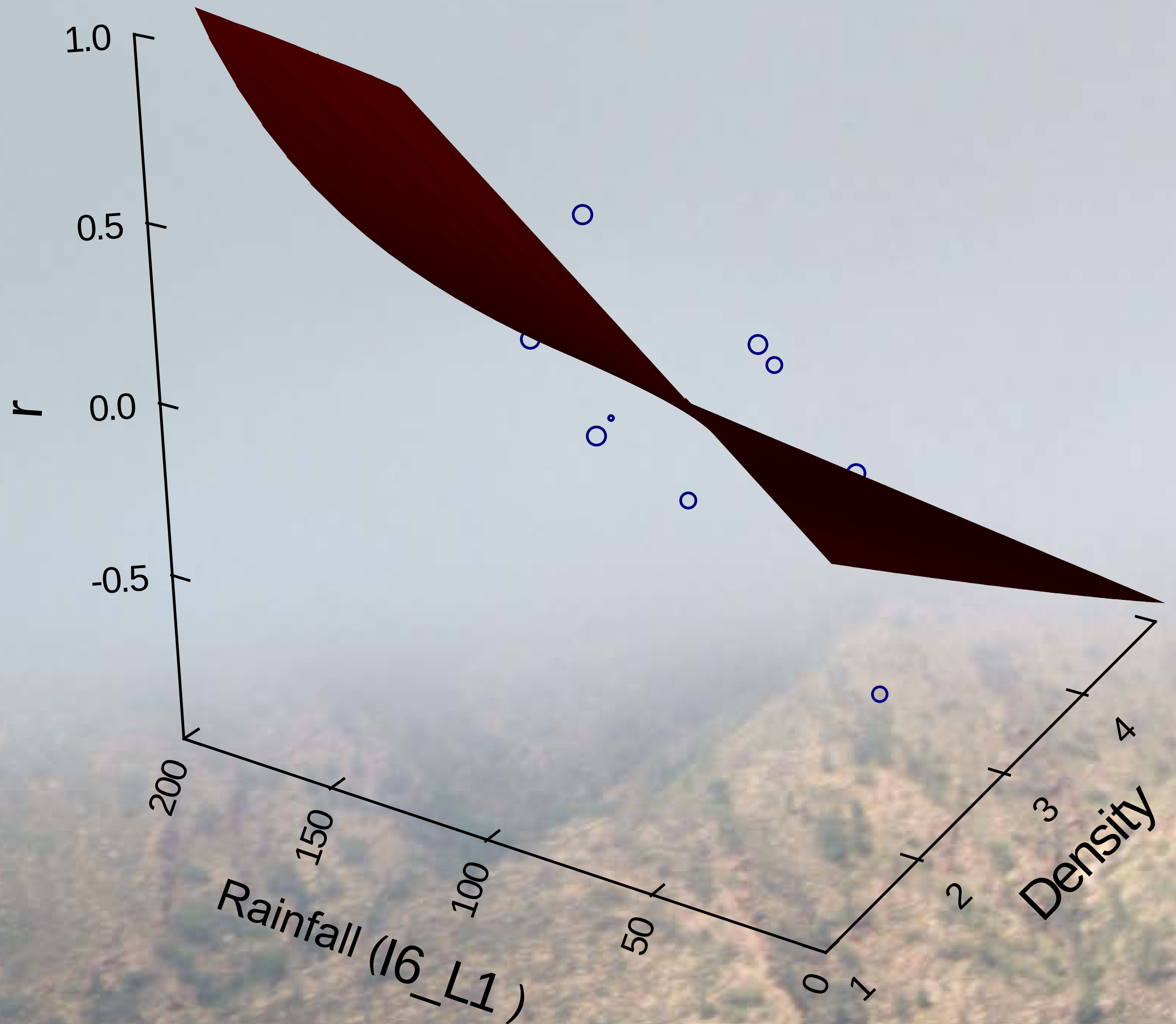
Summer and Autumn – driest months



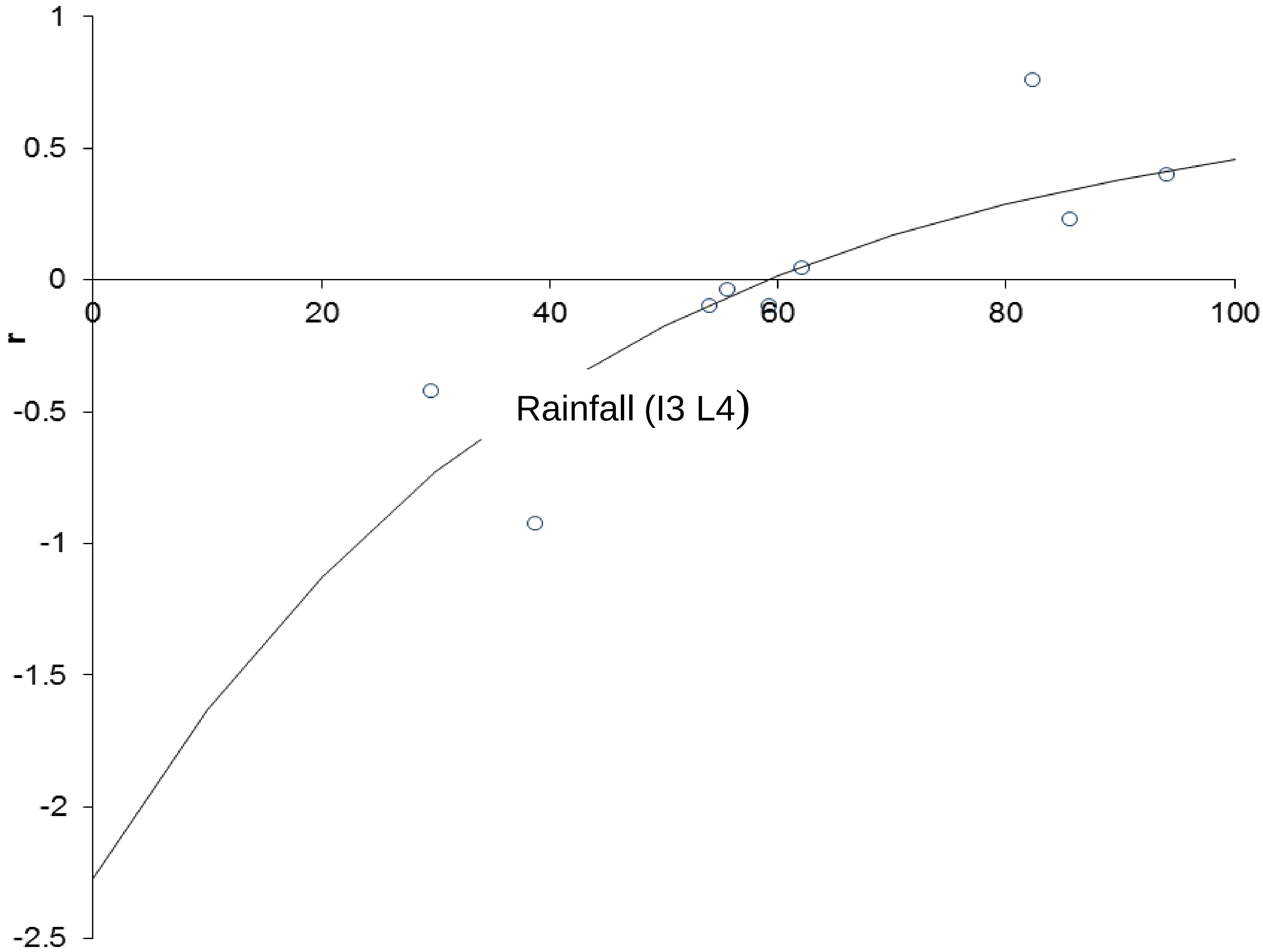
Best models for each zone after a QAIC and AIC, QAICc etc tests

Zone	Model	Rainfall Interval/Lag	R^2
Hawker	$-a+c(1-e^{-dv})$	I3 L4	0.73
Bimbowrie Stn	$-a+c(1-e^{-dv/D})$ - gD	I3 L0	0.77
Gammon Ranges	$-a+c(1-e^{-dv})$	I3 L4	0.48
Depot Flat	$-a+c(1-e^{-dv})$	I4 L1	0.40
Bunker Nth	$-a+c(1-e^{-dv})$	I3 L1	0.48
Plumbago Stn	$-a+c(1-e^{-dv/D})$ - gD	I4 L0	0.68
ABC Range	$-a+c(1-e^{-dv})$ - gD	I6 L1	0.61

Density/Rainfall interaction with population growth rate *r*



Rainfall versus population growth rate only



Climate model selection

- Used a combination of climate models coupled with low, moderate and high climate sensitivity.

- GCMs provided by CSIRO were generated for 2030, under the medium emissions scenario (A1B) and for 2070, they were generated under both low (B1) and high emissions scenarios (A1F1).

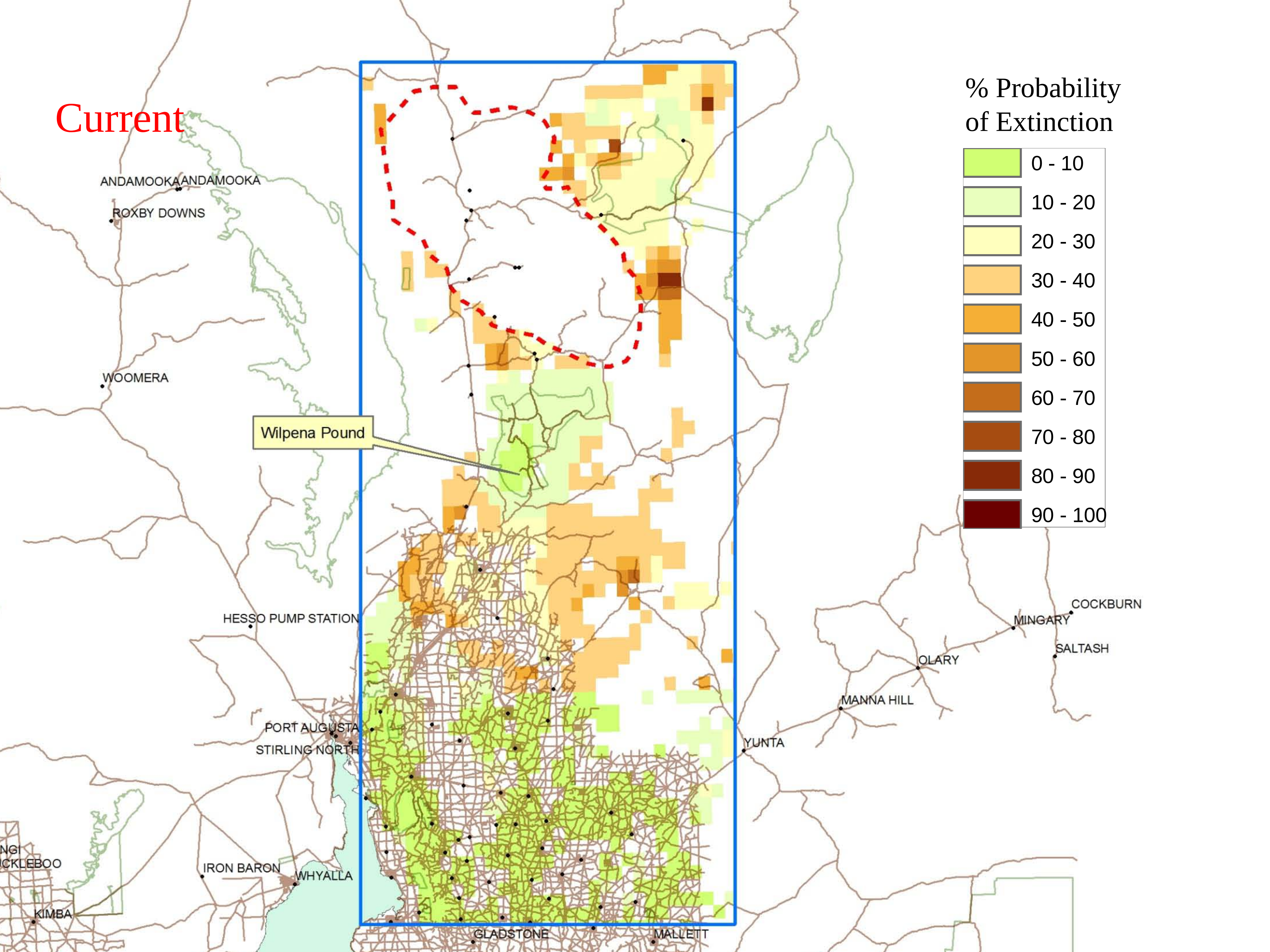
- Three climate futures were of interest:
  - most likely, represented by the greatest number of models,
  - driest, those with the greatest projected reduction in annual rainfall and,
  - wettest, those with the greatest projected increase in annual rainfall.

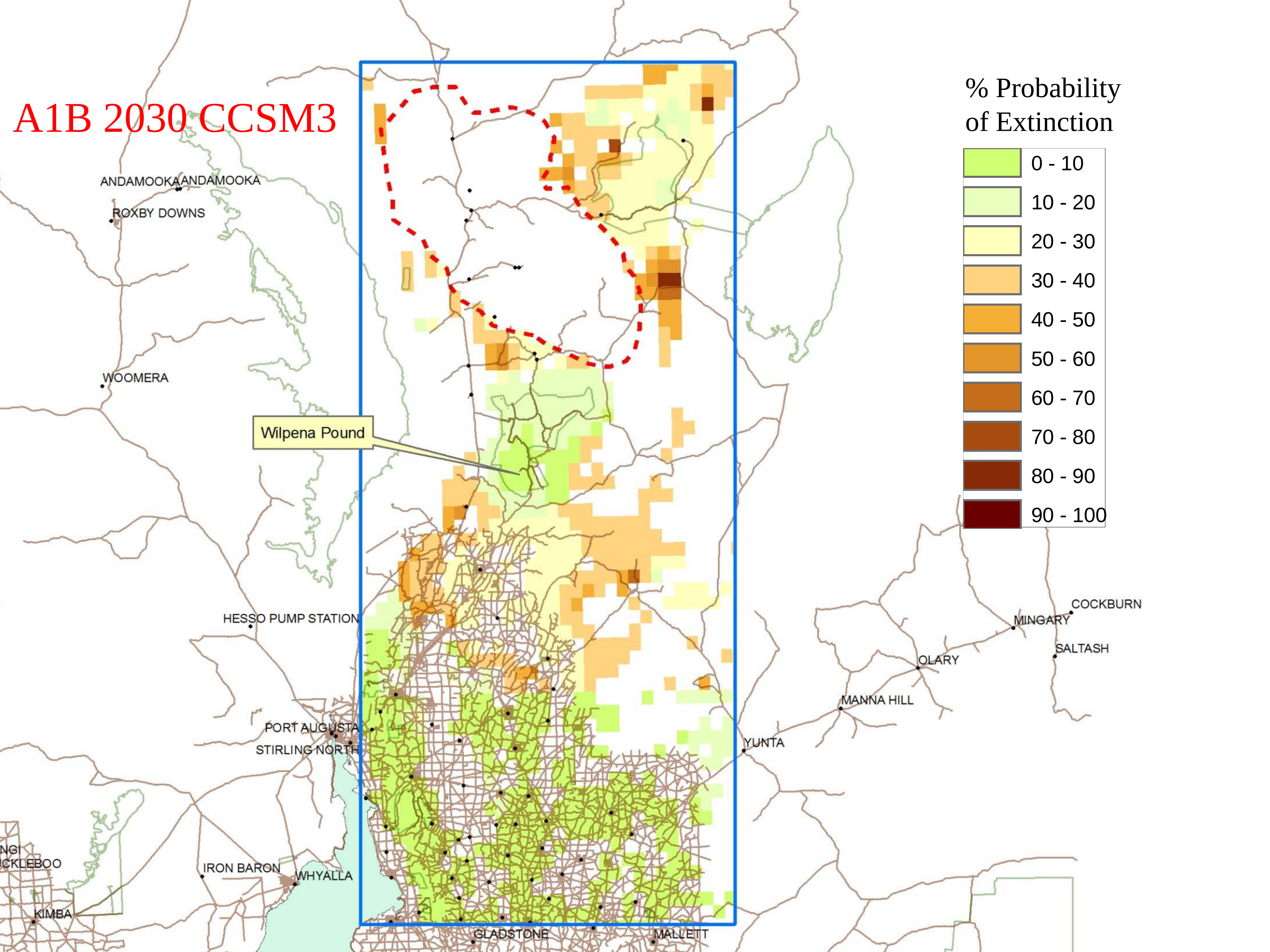
- A total of 22 global models were considered and models identified as performing badly across Australia by Smith and Chandler (2010) were excluded.

Climate model selection

- The performance of each model is assessed according to how well they produce observed seasonal patterns over the Australian continent.
- Like Smith and Chandler (2010) and Wheeton et al (2007), we were only interested in rainfall projections.
- Thus rainfall was the only measure used to assess model performance. This assessment was carried out in the Flinders Ranges of South Australia.
- A sub-set of models is then selected, based on the assumption that models which perform similarly in a particular area, and for a given emission scenario, also tend to yield similar changes in rainfall.

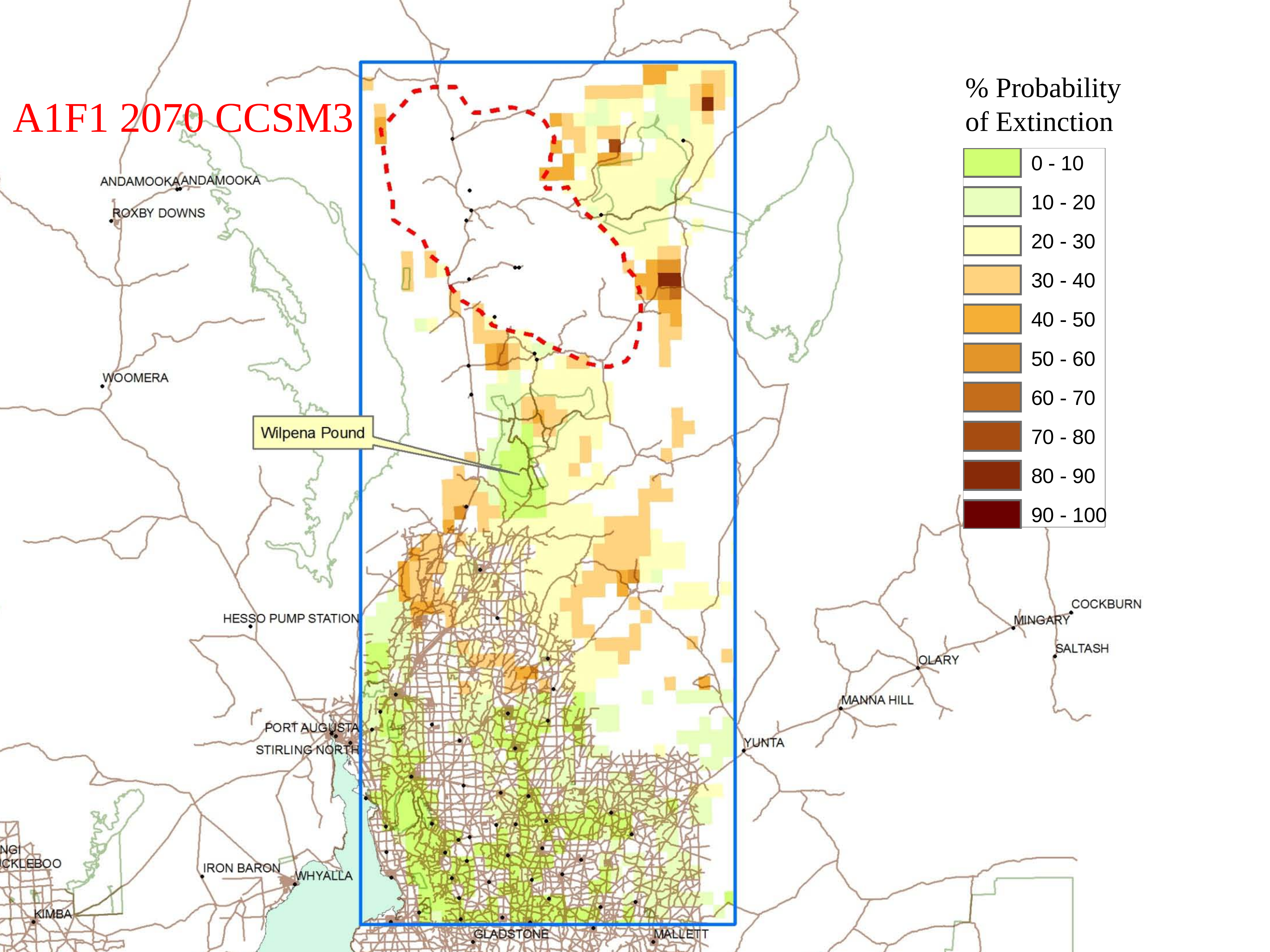
	Slightly Warmer <0.5	Warmer 0.5 to 1.5	Hotter 1.5 to 3.0	Much hotter > 3.0
Much drier < -15.0				2070: A1F1 (7) Most Likely CCSM3 2070: A1F1 (7) CSIRO-Mk3.5
Drier -5.0 to -15.0		2030: A1B (5) CSIRO-Mk3.5 2070: B1 (6) CSIRO-Mk3.5		
Little Change -5.0 to 5.0		2030: A1B (19) Most Likely CCSM3 2030: A1B (19) MIROC3.2(medres) 2070: B1 (18) Most Likely CCSM3 2070: B1 (18) MIROC3.2(medres)		
Wetter 5.0 to 15.0				
Much Wetter > 15.0				2070: B1 (1) MIROC3.2(medres)


Current
% Probability of Extinction
0 - 10
10 - 20
20 - 30
30 - 40
40 - 50
50 - 60
60 - 70
70 - 80
80 - 90
90 - 100
ANDAMOOKA
ANDAMOOKA
ROXBY DOWNS
WOOMERA
Wilpena Pound
HESSO PUMP STATION
PORT AUGUSTA
STIRLING NORTH
IRON BARON
WHYALLA
KIMBA
GLADSTONE
MALLETT
YUNTA
MANNA HILL
OLARY
MINGARY
COCKBURN
SALTASH

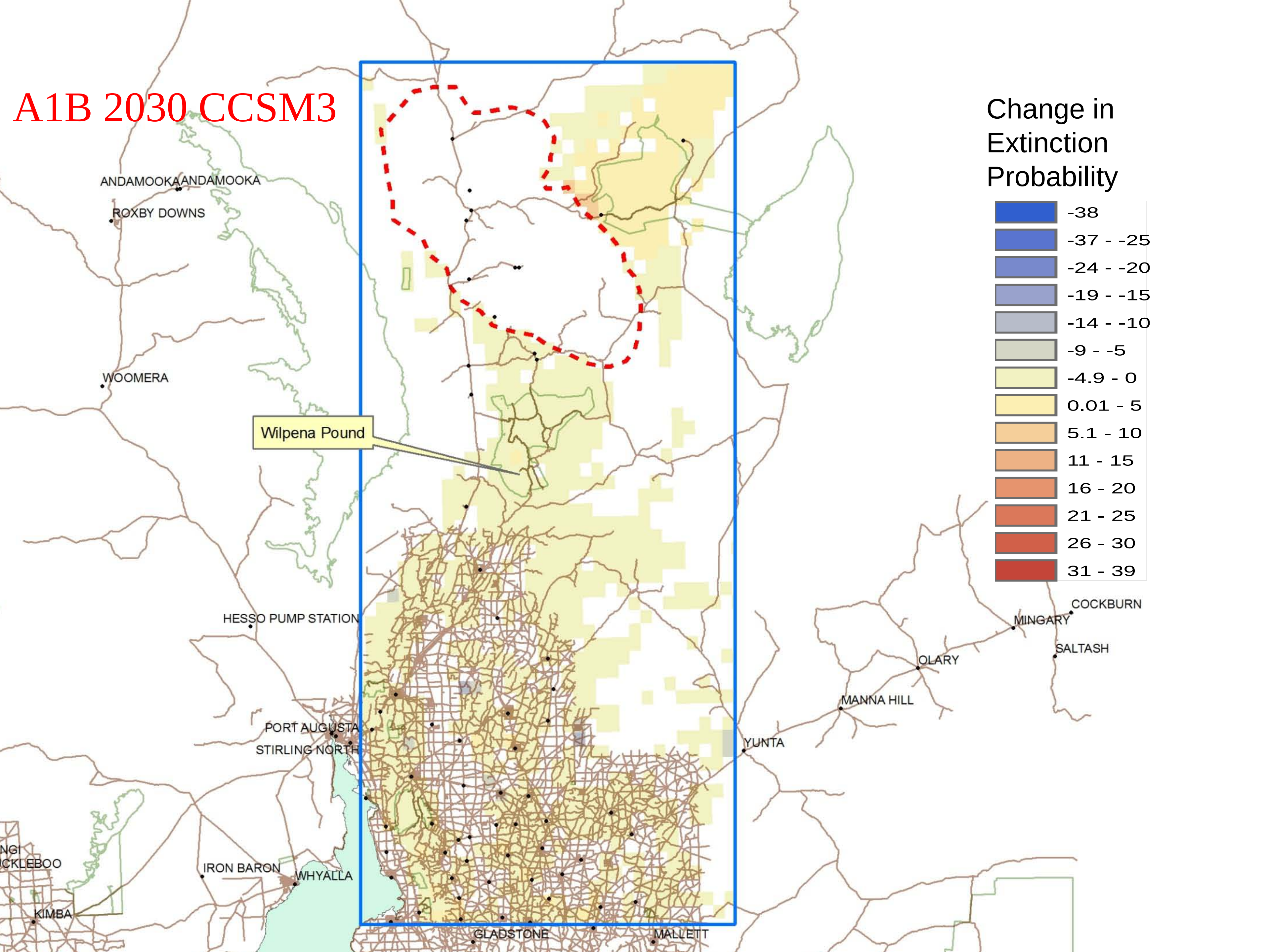


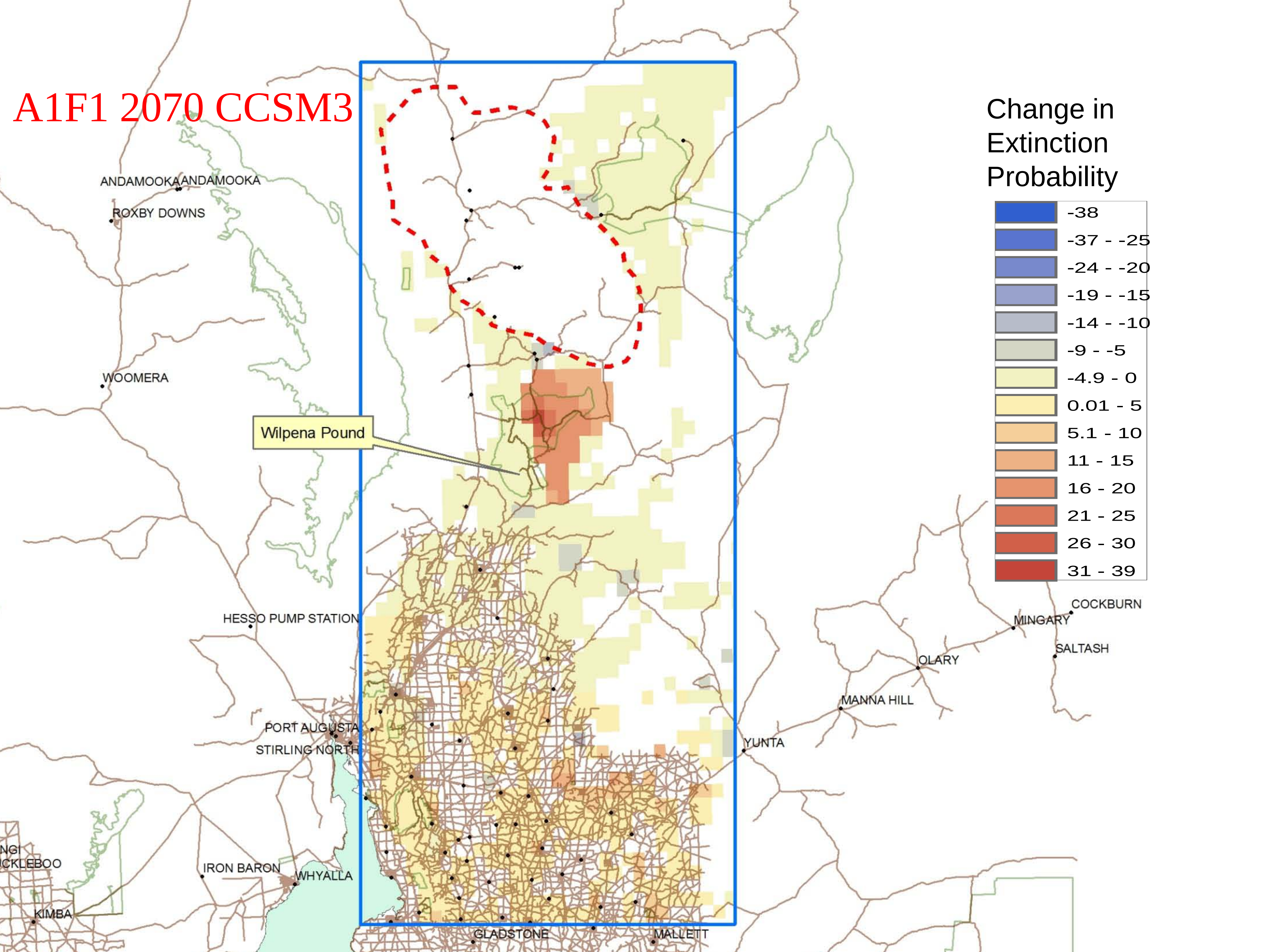
A1B 2030 CCSM3
% Probability of Extinction
0 - 10
10 - 20
20 - 30
30 - 40
40 - 50
50 - 60
60 - 70
70 - 80
80 - 90
90 - 100
Wilpena Pound
ANDAMOOKA
ANDAMOOKA
ROXBY DOWNS
WOOMERA
HESSO PUMP STATION
PORT AUGUSTA
STIRLING NORTH
IRON BARON
WHYALLA
KIMBA
GLADSTONE
MALLETT
YUNTA
MANNA HILL
OLARY
MINGARY
COCKBURN
SALTASH

A1F1 2070 CCSM3



A1B 2030 CCSM3




A1F1 2070 CCSM3
Change in Extinction Probability
-38
-37 - -25
-24 - -20
-19 - -15
-14 - -10
-9 - -5
-4.9 - 0
0.01 - 5
5.1 - 10
11 - 15
16 - 20
21 - 25
26 - 30
31 - 39
Wilpena Pound
ANDAMOOKA
ANDAMOOKA
ROXBY DOWNS
WOOMERA
HESSO PUMP STATION
PORT AUGUSTA
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An alternative approach

Environmental Envelopes

Species are thought to live in climate envelopes.

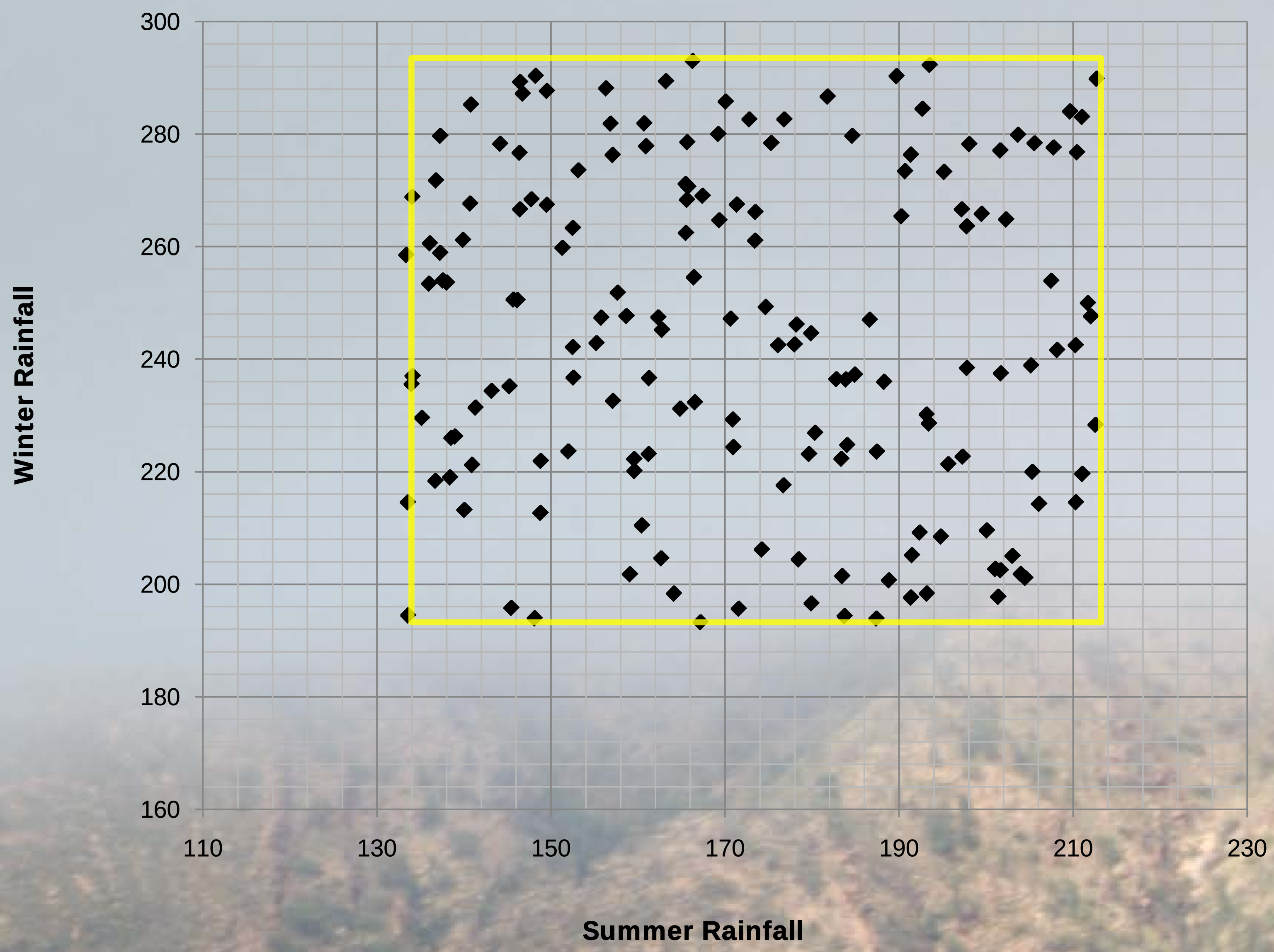
Envelopes are the minimum and maximum of:

- temperature, rainfall (annual, summer, winter etc), solar radiation and humidity.

They may also tolerate only a limited variability in these climate parameters.

Species may also live in certain environmental niches of soil, geology and topography.

Example


Winter Rainfall
300
280
260
240
220
200
180
160
110
130
150
170
190
210
230
Summer Rainfall

The data

Opportunistic sightings, aerial and ground survey data from DENR, collected by Copley (1984) and Lethbridge (2001, 2003, 2009, 2010) for *P. x. xanthopus.*

Environmental Envelopes

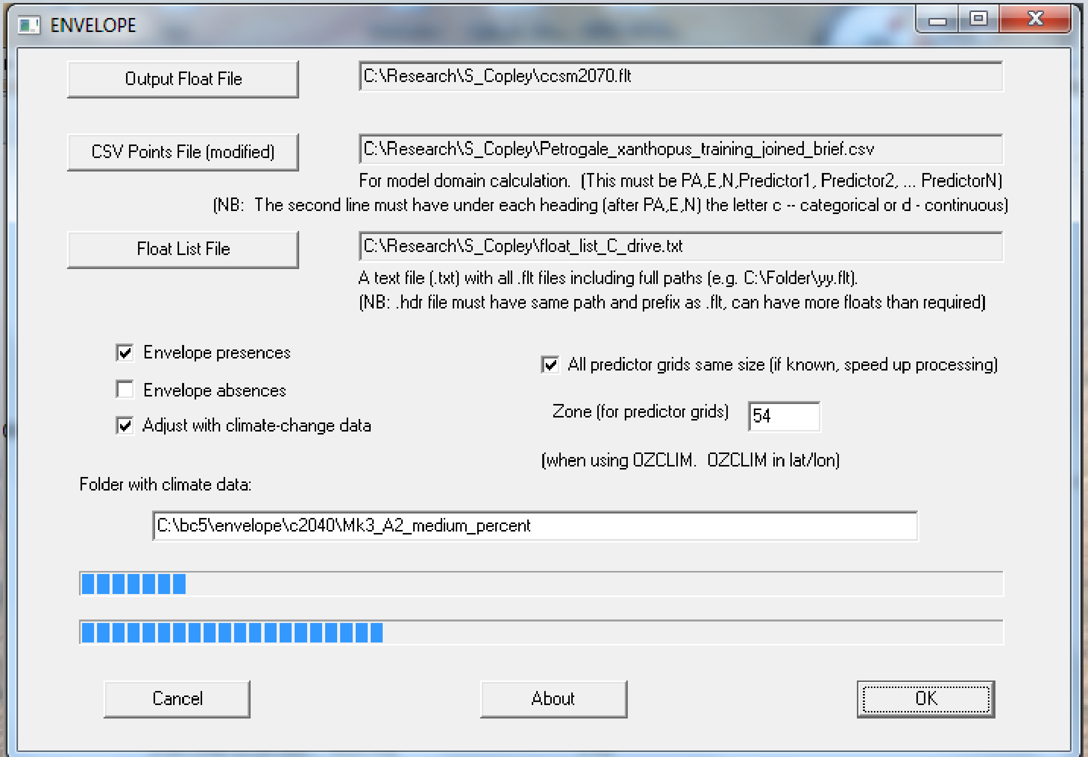
1. Used a range of BIOCLIM predictors:
    - Wettest season rainfall
    - Driest season rainfall
    - Annual rainfall
2. Added local topographic and geological data:
    - Geology
    - Slope
    - Elevation
    - Terrain microclimate measures
3. Spatially overlaid presence data on BIOCLIM, geology and topographic data

Environmental Envelopes

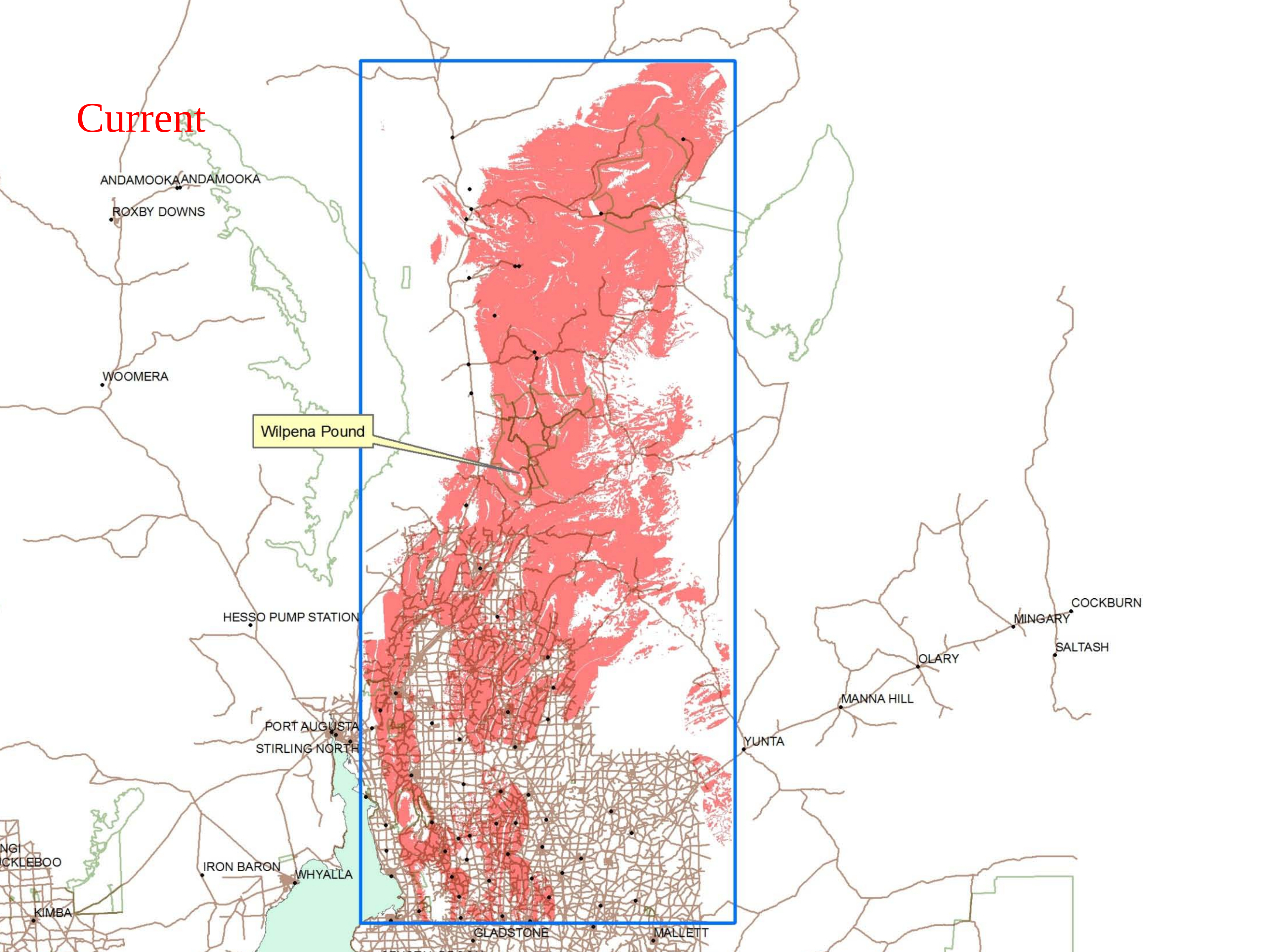
4. Established environmental envelopes (max/min ranges) based on current climate conditions, topography and categories of Geology.

5. Adjusted the climate layers according to the OZCLIM climate-change scenarios (5 km grid cells).

6. Predict the spatial range based on the envelopes (before and after OZCLIM adjustments)



Current


ANDAMOOKA
ANDAMOOKA
ROXBY DOWNS
WOOMERA
Wilpena Pound
HESSO PUMP STATION
PORT AUGUSTA
STIRLING NORTH
IRON BARON
WHYALLA
KIMBA
GLADSTONE
MALLETT
YUNTA
MANNA HILL
OLARY
MINGARY
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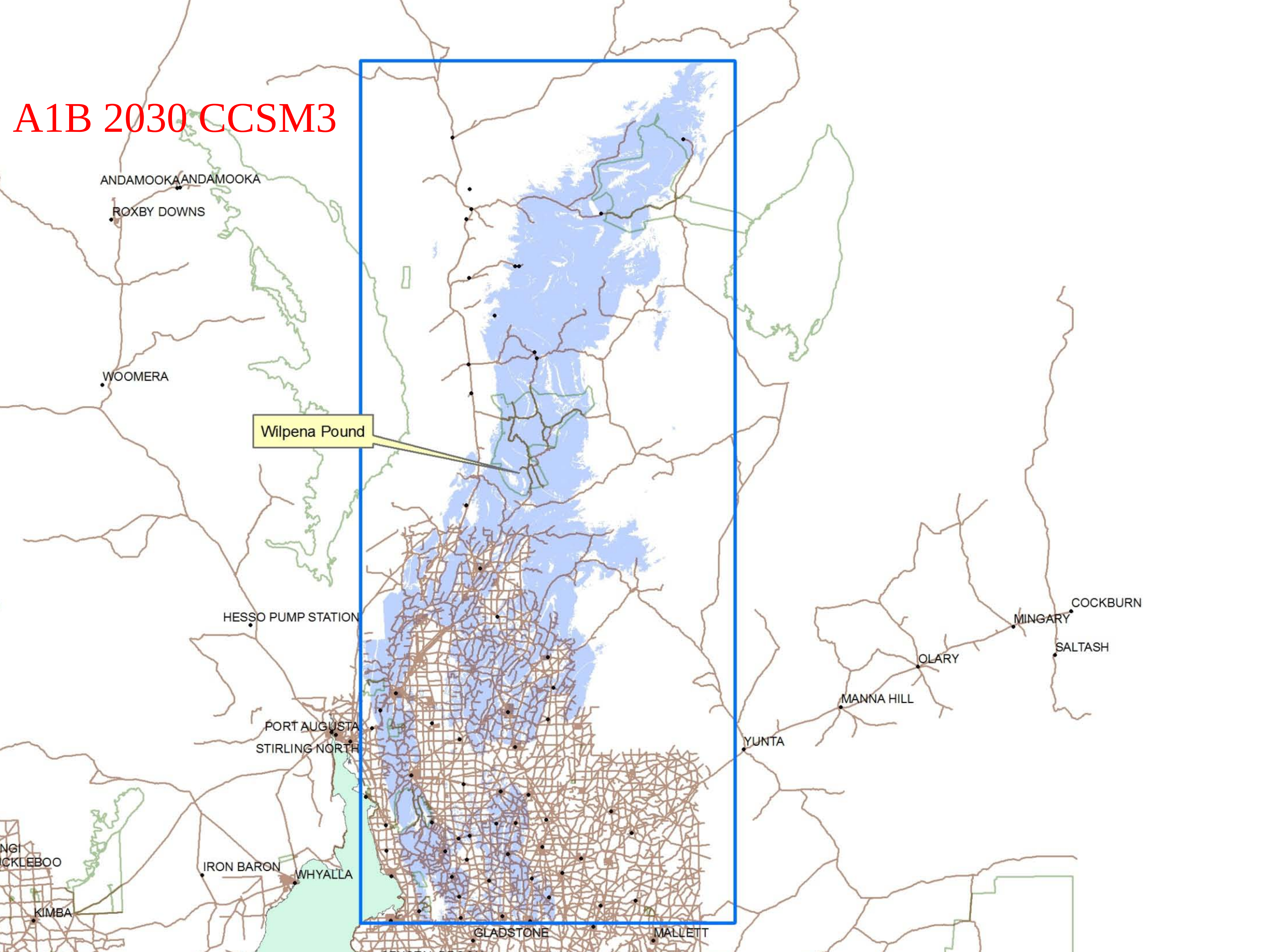
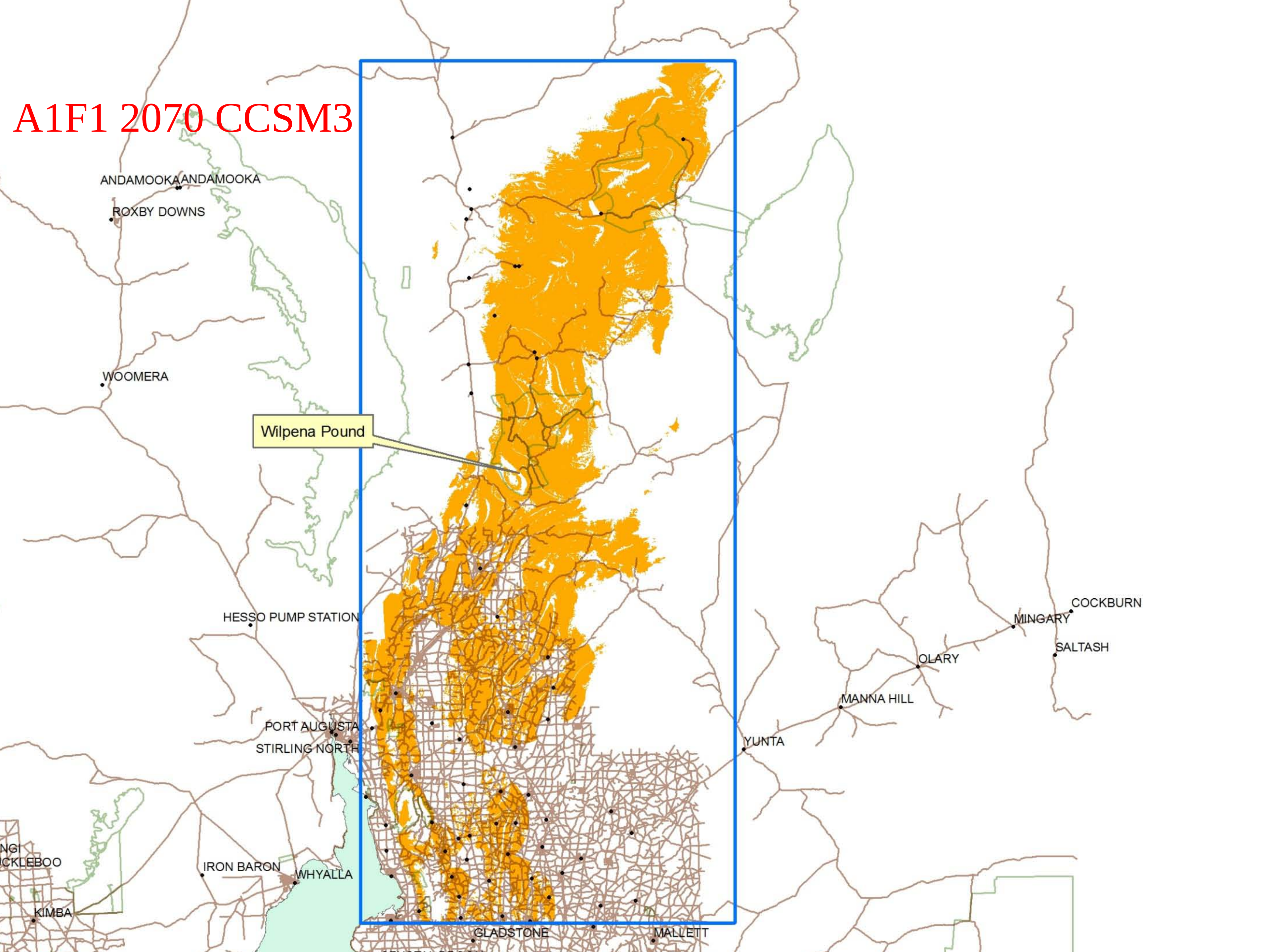
A1B 2030 CCSM3



A1F1 2070 CCSM3




DODGY

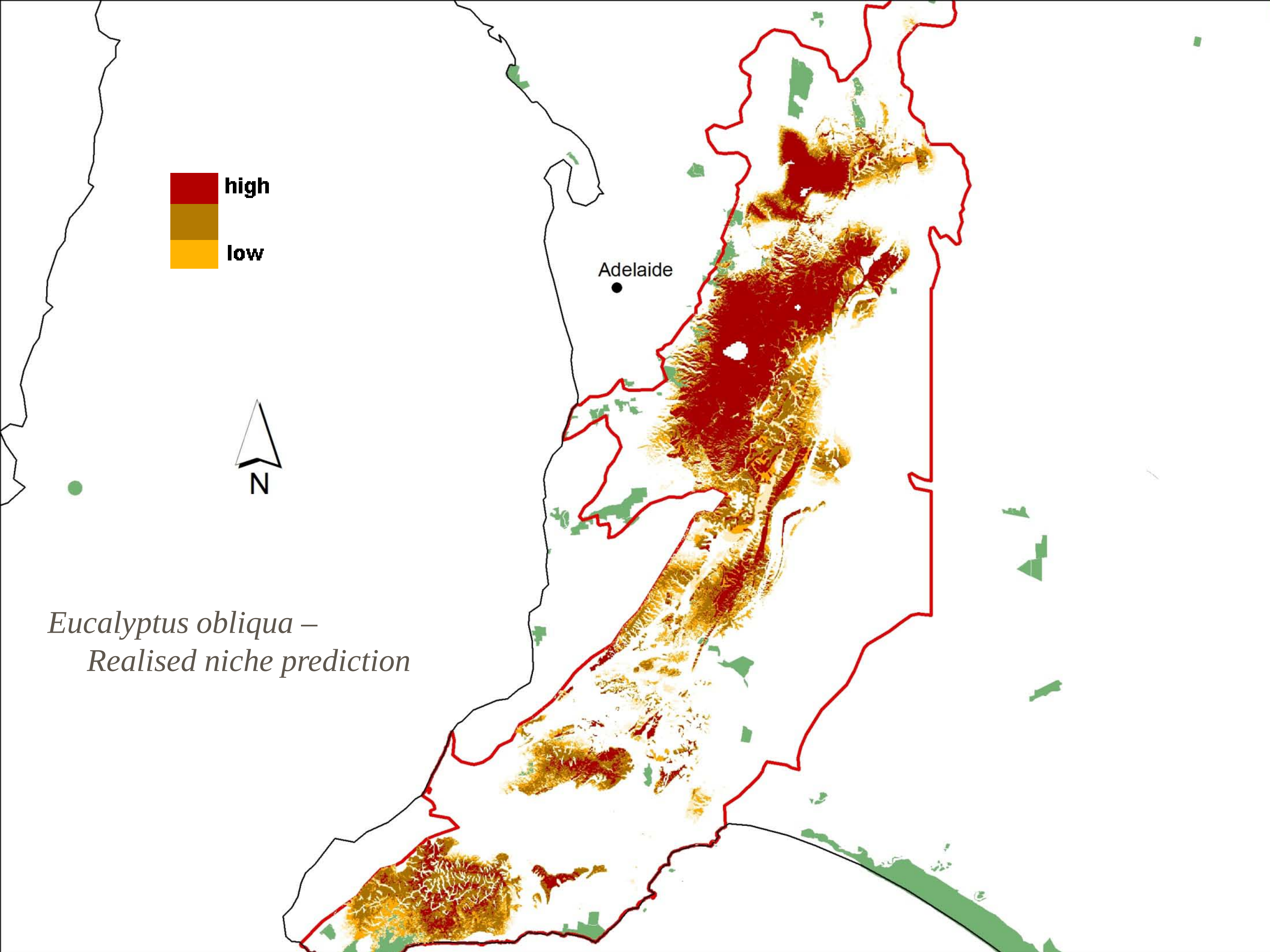
Why?

- Envelope models are too abstract and better suited to bio-geographical (continental) scales.
- Do not consider density dependence issues.
- Lack transparency and do not use any underpinning biological or ecological drivers.

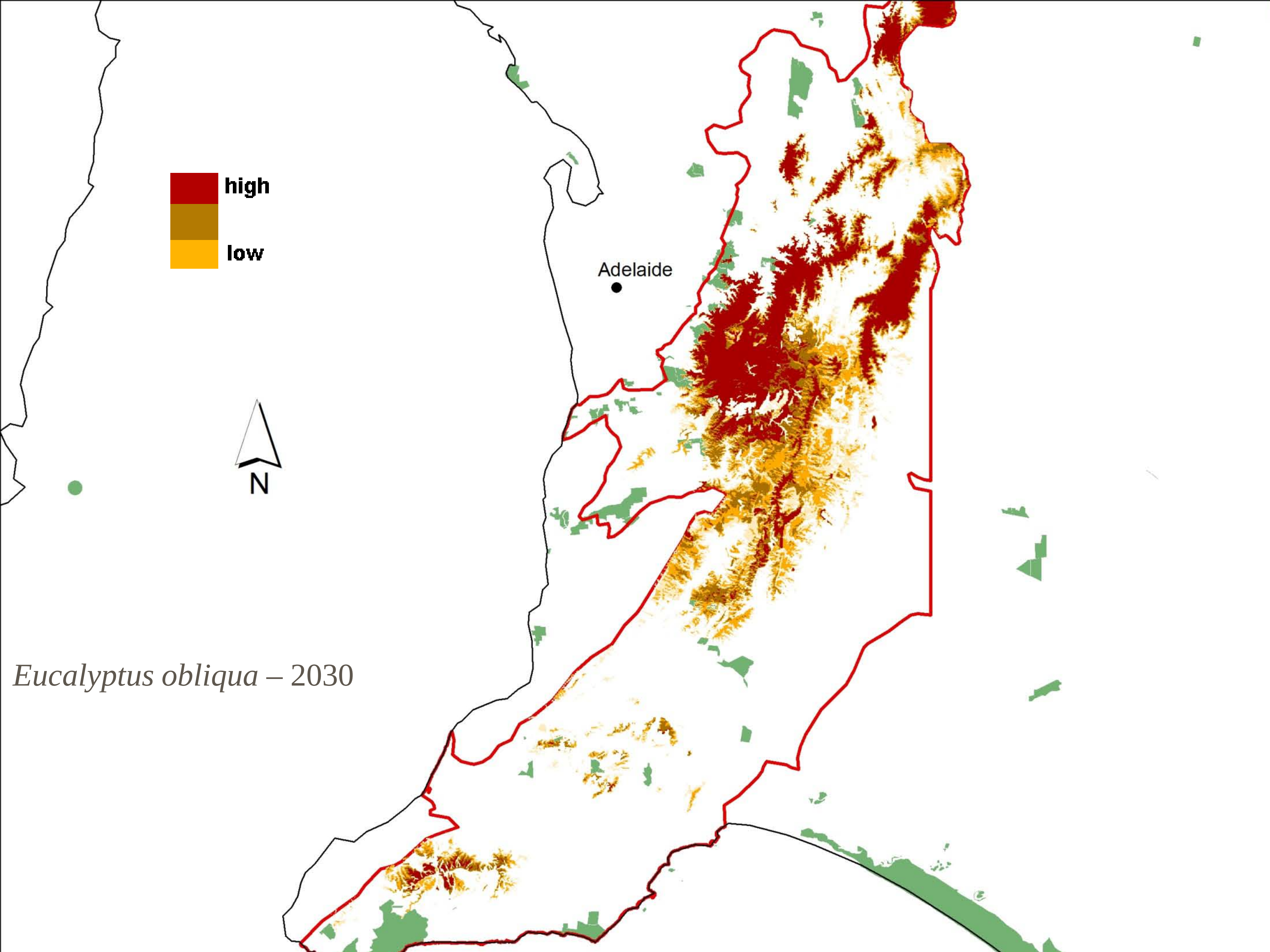

Why trust either?

Neither approach adequately considers:

- How extreme events can disrupt/alter breeding cycles.
- Habitat fragmentation and its relationship to movement and gene flow.
- Interactive effects with other species.
  - Competition – e.g. increased pressure around permanent water.
  - Predation – e.g. increased susceptibility to predation .
  - Parasitism – e.g. plant insect attack from leaf eaters, borers
  - Changes in species composition/assemblages
- Pest species capitalising on disturbance (weeds, vertebrate pests).
- Behavioral responses like territoriality.
- Genetic diversity and adaptation.
- The extent to which wildlife health and disease is facilitated and exacerbates impact – e.g. increasing in virus vectors and host susceptibility
- Adaptation
- Connectivity and dispersal capacity
- Compounding effects of all of the above



Eucalyptus obliqua –
Realised niche prediction



Eucalyptus obliqua – 2030

Where research is needed

Population trend data

Few demographics and life history data available (more collection, similar species?)

Wildlife health and disease

- Predispositions:
  - health - collecting /modelling chronic stress measures @ landscape
- Vectors
  - tracking/modelling disease vectors - spatial

Genetic/adaptation understanding at landscape scale (climate scale)

- Inbreeding depression, diversity, proportion of shared alleles

- Understanding how spatial genetic patterns respond to landscape and climate change

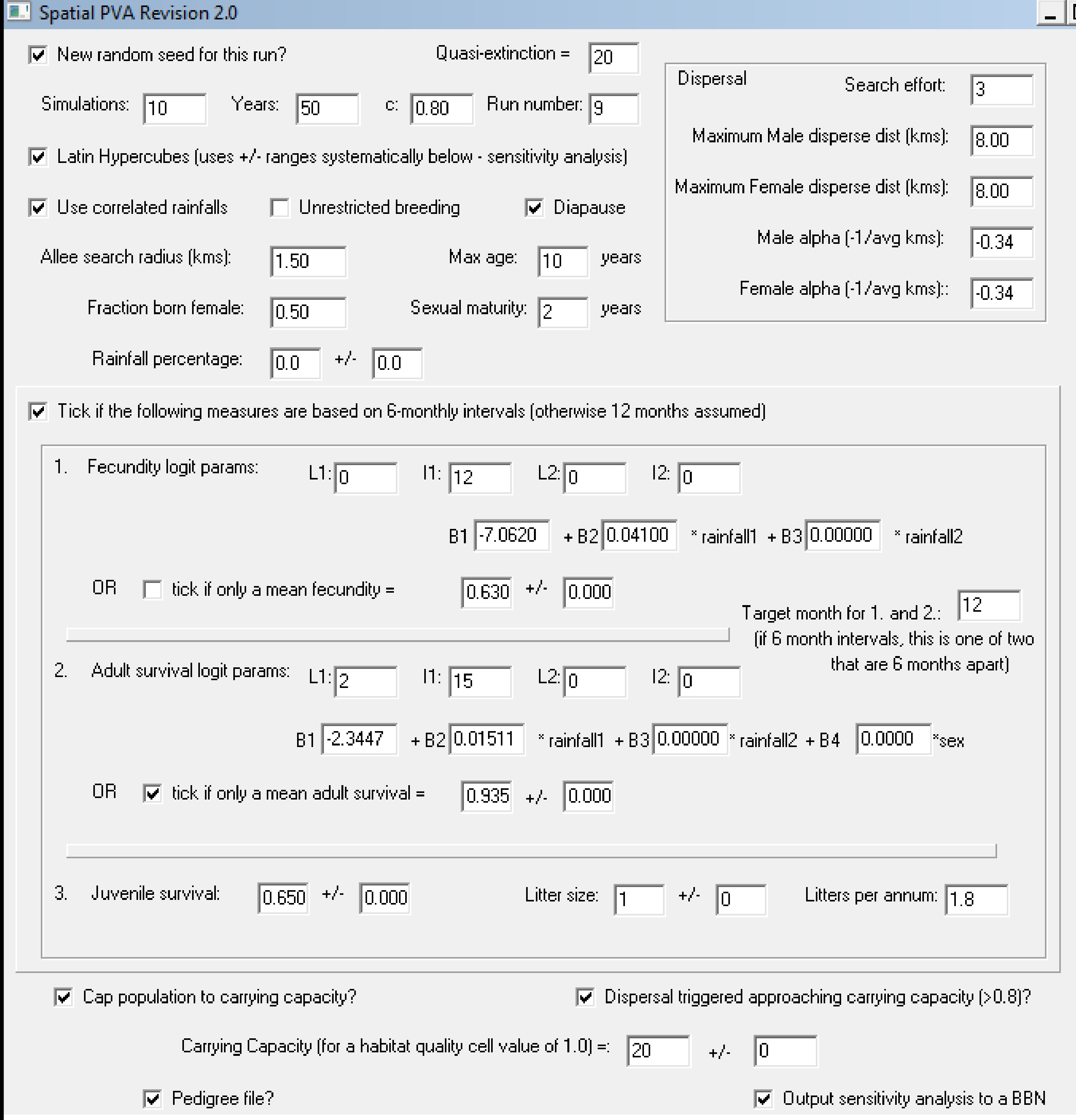
PVA

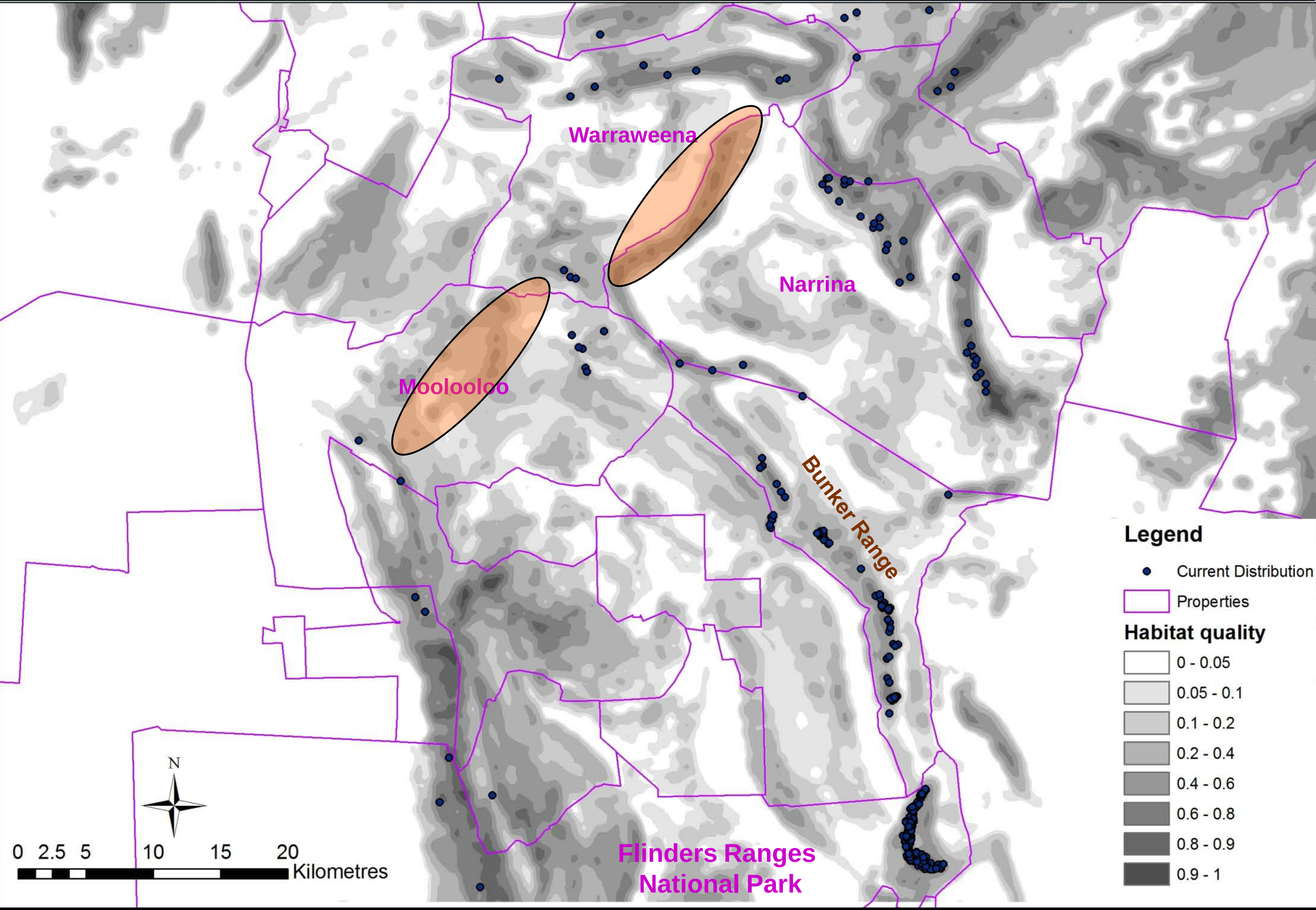
Individual-based,

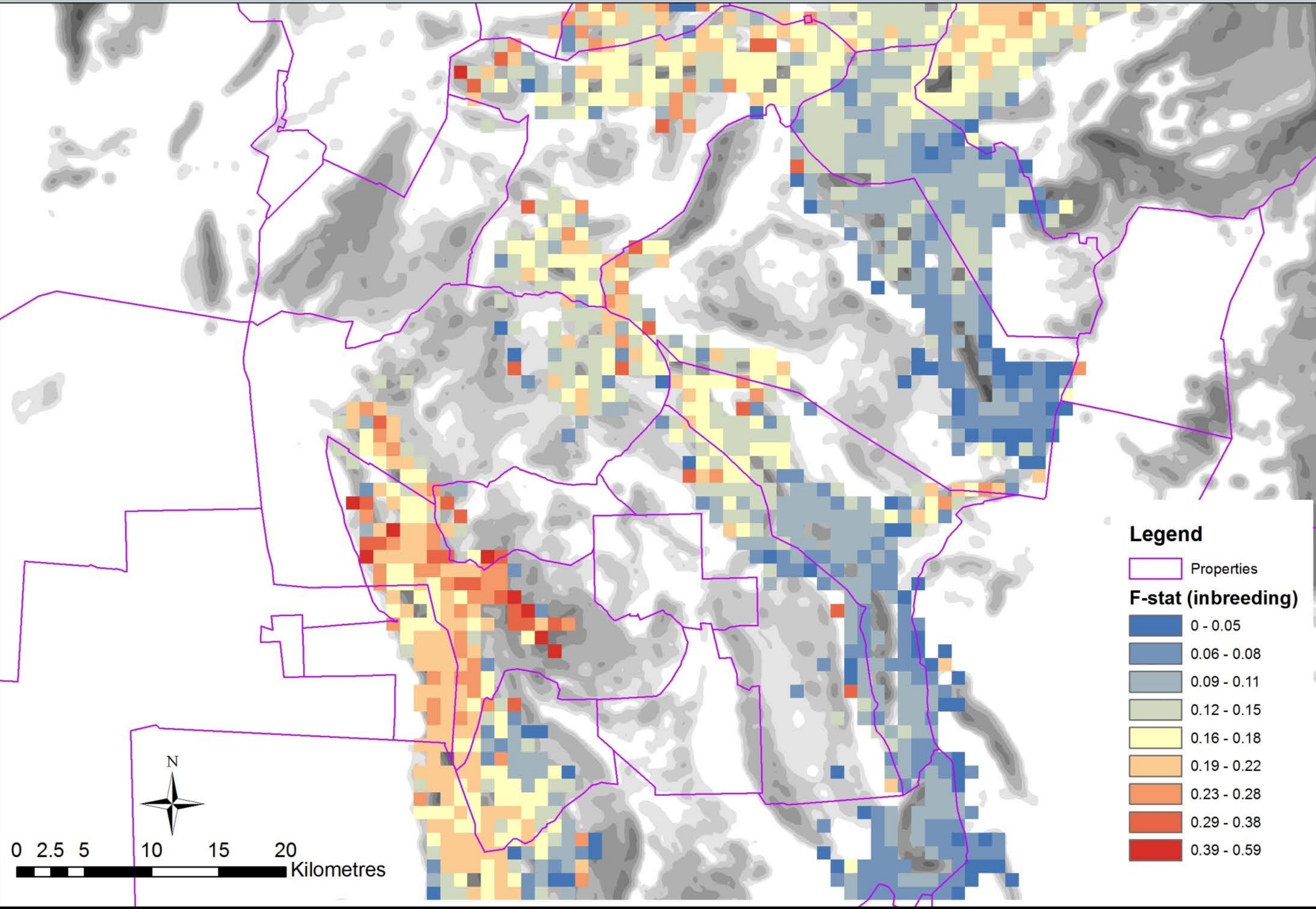
Spatially-explicit,

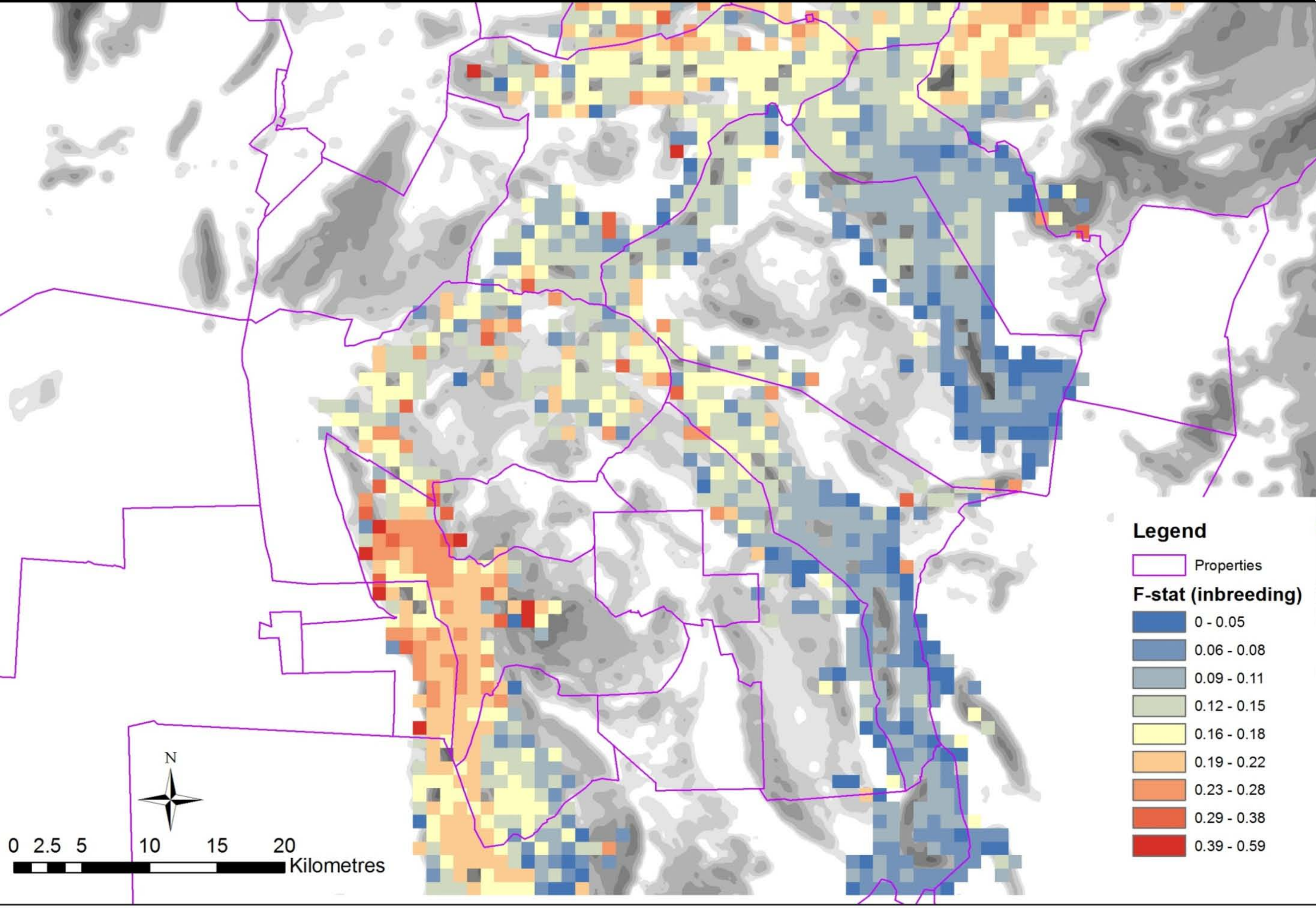
Models breeding structures, gene flow and movement

Use life history and movement data




Warraweena
Narrina
Mooloooloo
Bunker Range
Flinders Ranges
National Park
Legend
Current Distribution
Properties
Habitat quality
0 - 0.05
0.05 - 0.1
0.1 - 0.2
0.2 - 0.4
0.4 - 0.6
0.6 - 0.8
0.8 - 0.9
0.9 - 1
N
0 2.5 5 10 15 20
Kilometres


Legend
Properties
F-stat (inbreeding)
0 - 0.05
0.06 - 0.08
0.09 - 0.11
0.12 - 0.15
0.16 - 0.18
0.19 - 0.22
0.23 - 0.28
0.29 - 0.38
0.39 - 0.59
N
0 2.5 5 10 15 20
Kilometres


Legend
Properties
F-stat (inbreeding)
0 - 0.05
0.06 - 0.08
0.09 - 0.11
0.12 - 0.15
0.16 - 0.18
0.19 - 0.22
0.23 - 0.28
0.29 - 0.38
0.39 - 0.59
N
0 2.5 5 10 15 20
Kilometres

Three tips for assessing and engaging “modellers”

Ask the “modeller” 10 natural history questions.

Keep the GIS wizz-kids away from the project and give them crayons to play with.

If a “modeller” uses the phrase “I can predict”, sack them.