National Environmental Research Program

Centre for Tropical Biodiversity & Climate Change

James Cook University Australia

Project 7.3: Climate change, extreme events and biodiversity in the Wet Tropics

Justin Welbergen, Andrew Krockenberger, Jeremy VanDerWal, Collin Storlie, Jessica Meade, Anastasia Dalziell, Lauren Hodgson, Johan Larson, Luke Shoo, Steve Williams

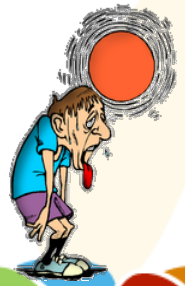
Justin A Welbergen

Centre for Tropical Biodiversity & Climate Change, James Cook University, Townsville, Australia

justin.welbergen@jcu.edu.au
tiny.cc/welbergen

Our world is warming

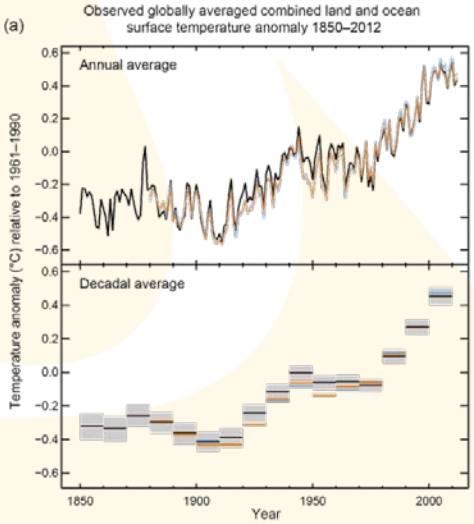


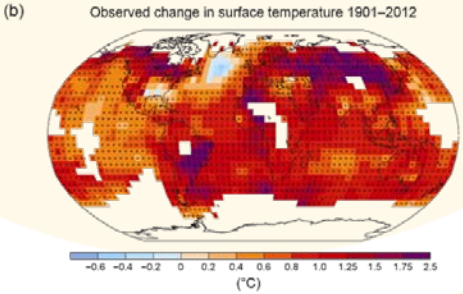



Our world is warming

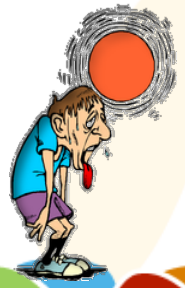



The instrumental record shows a clear upward trend in global land and ocean temperature since the early 20th century





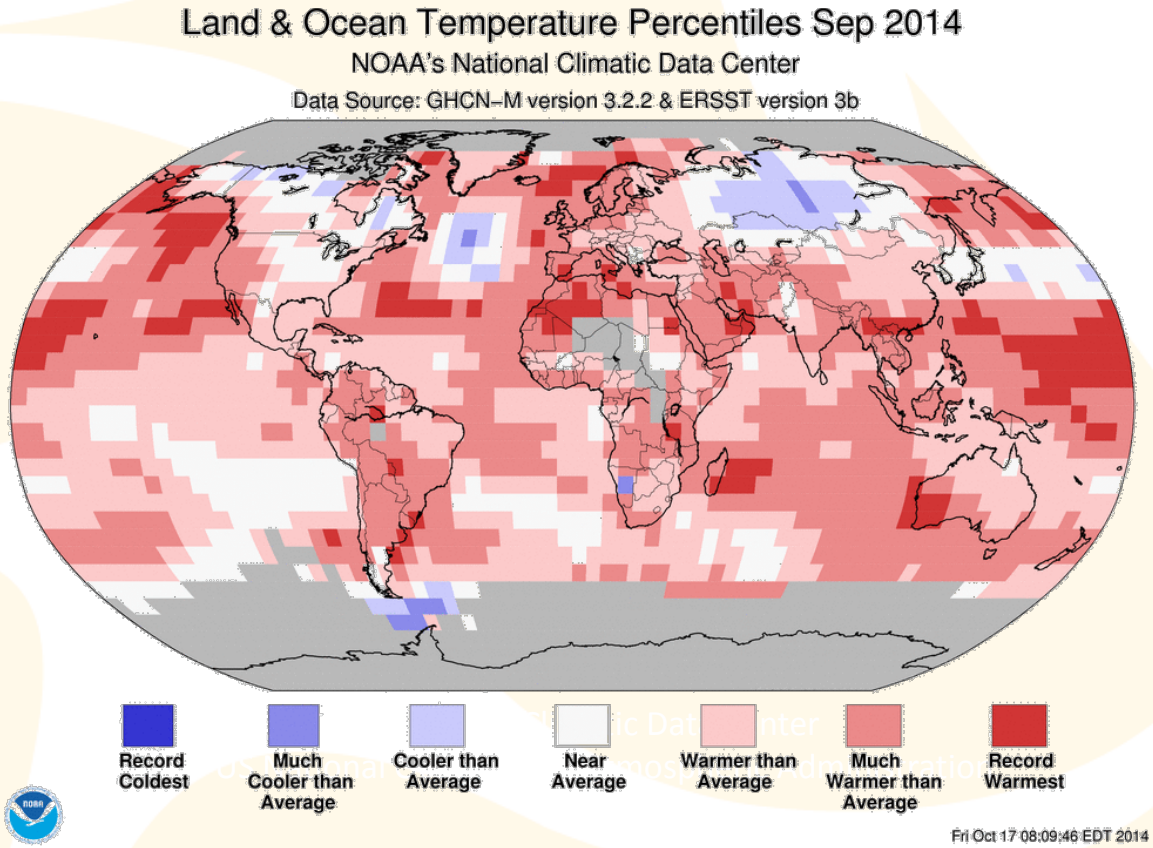
IPCC Fifth Assessment Report

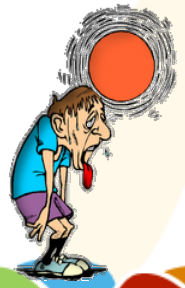


Our world is warming




Monthly temperature records are broken all the time:



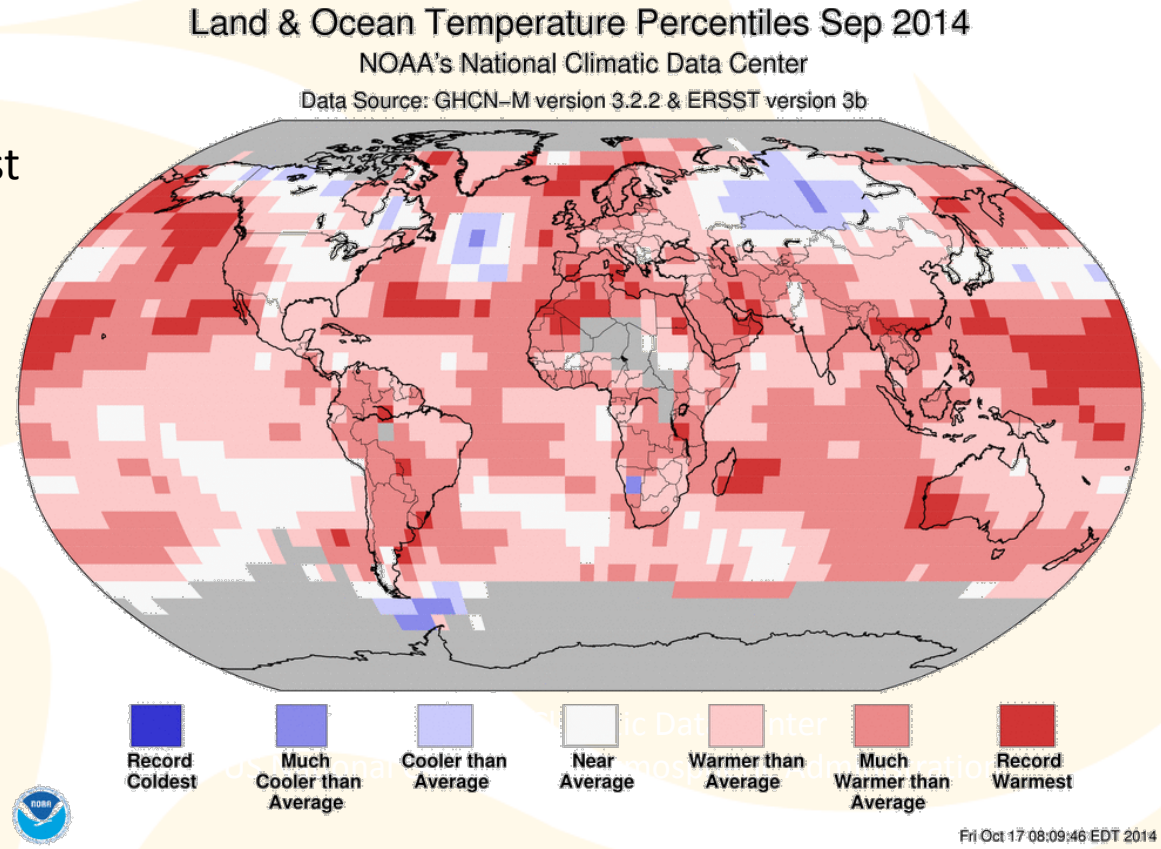


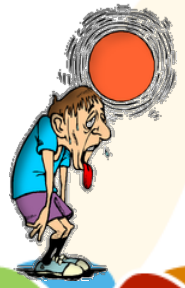
Our world is warming




Monthly temperature records are broken all the time:

- last September was the warmest on record



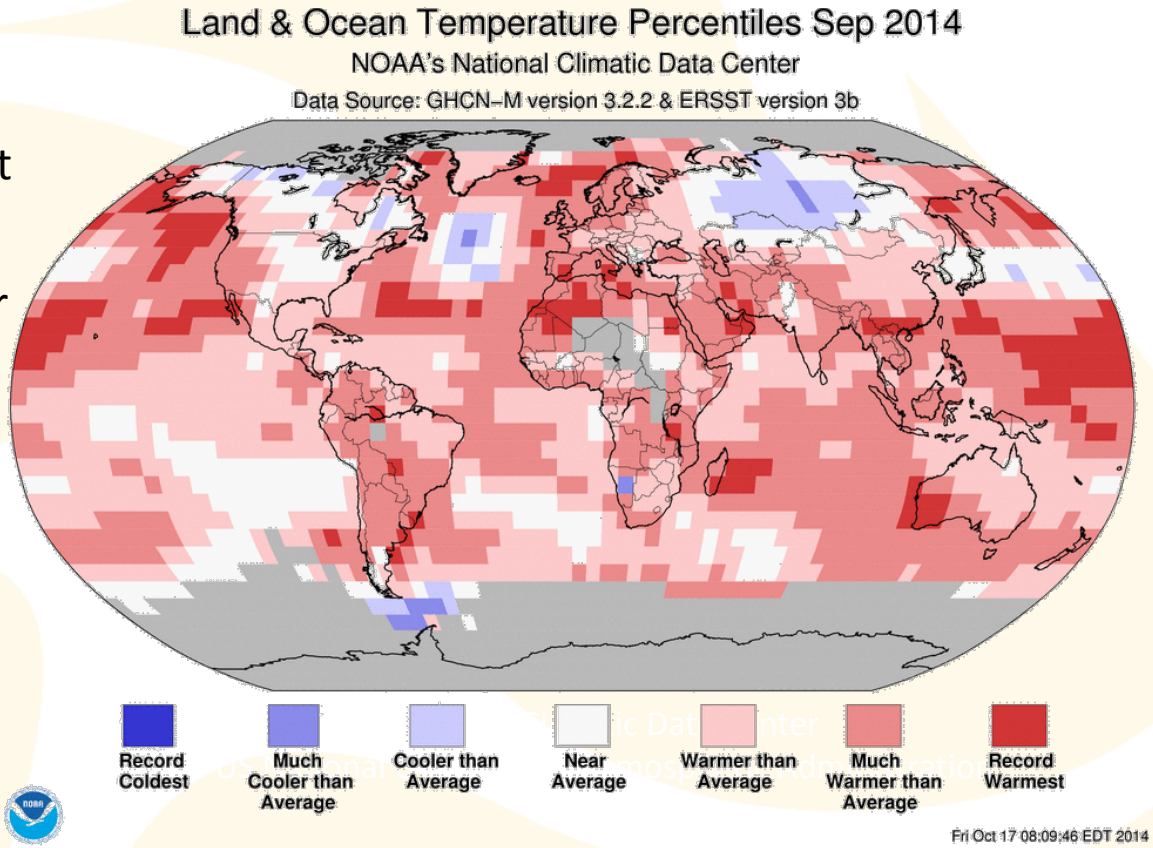


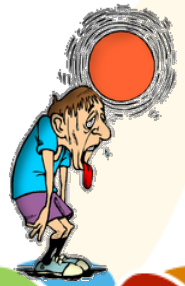
Our world is warming




Monthly temperature records are broken all the time:

- last September was the warmest on record
- the 38th consecutive September that was warmer than the 20th century average



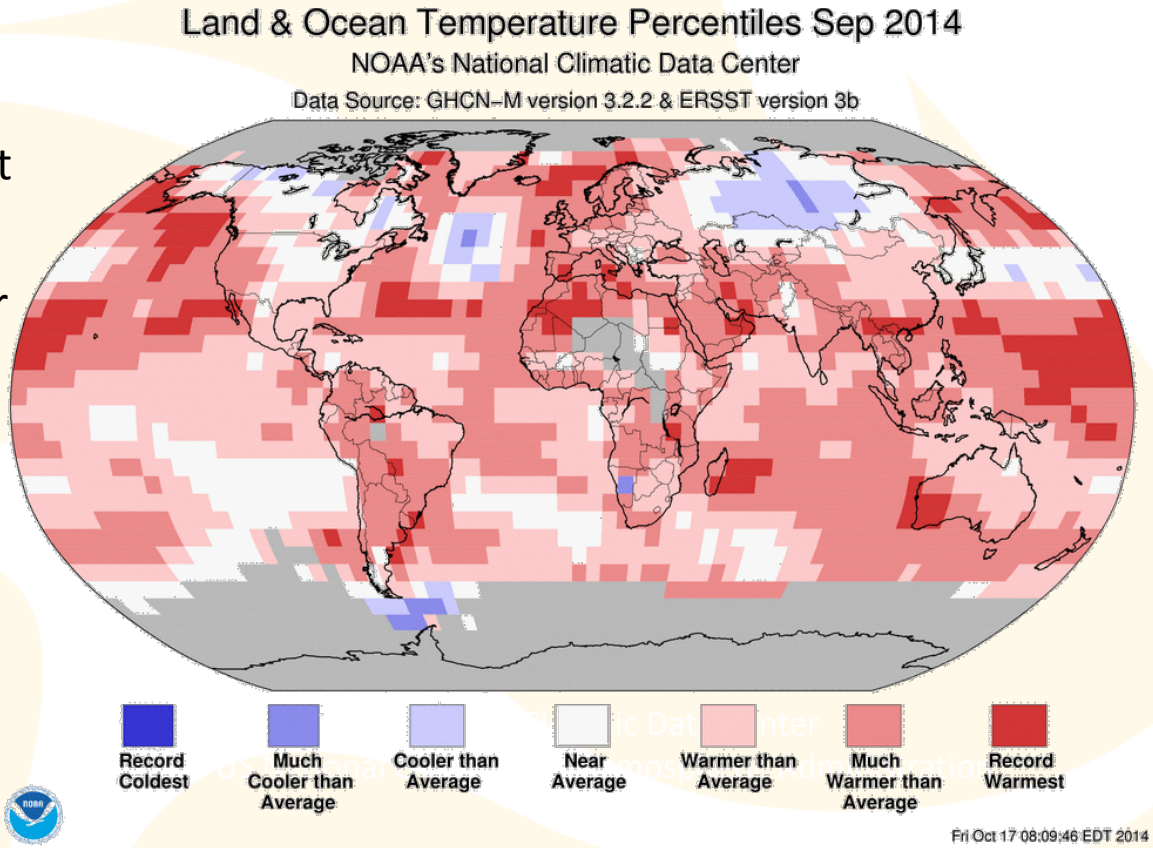


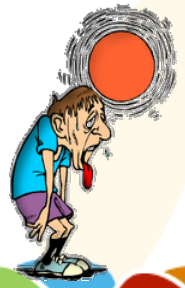
Our world is warming




Monthly temperature records are broken all the time:

- last September was the warmest on record
- the 38th consecutive September that was warmer than the 20th century average
- the 355th consecutive month that was warmer than the 20th century average

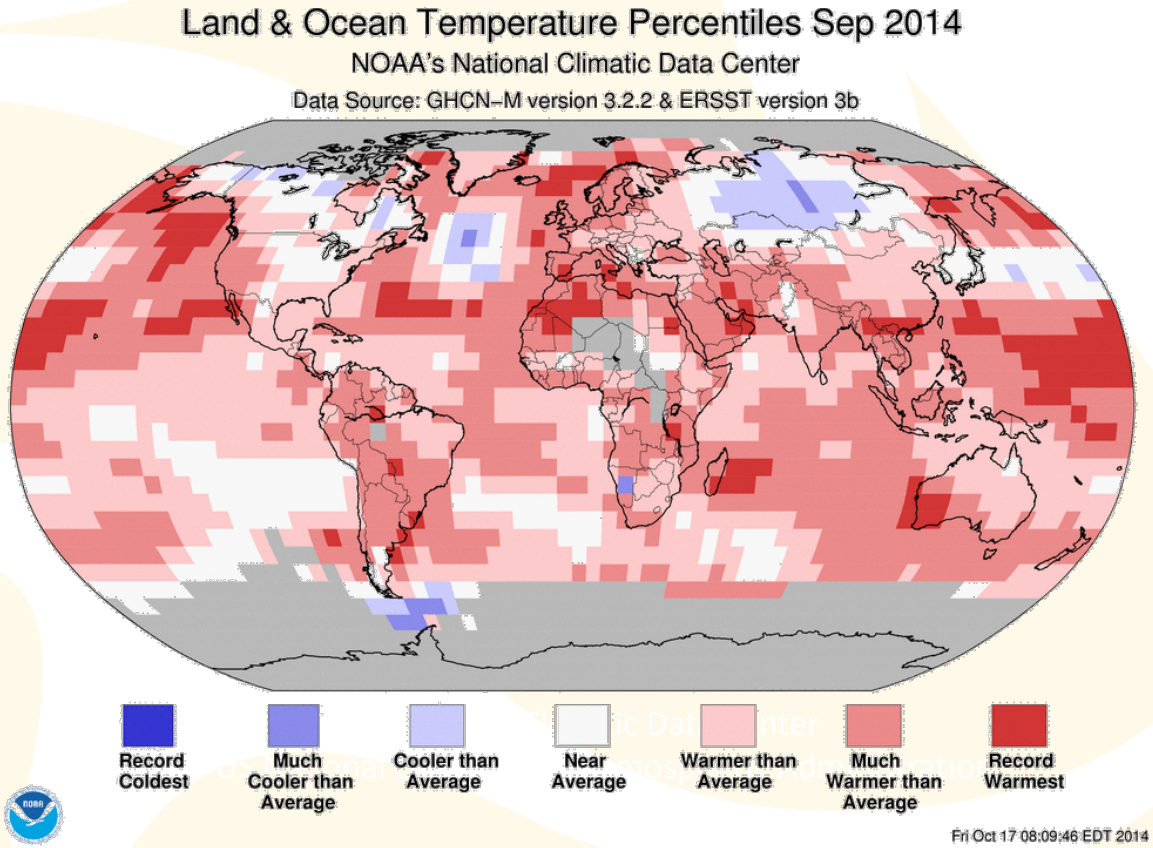


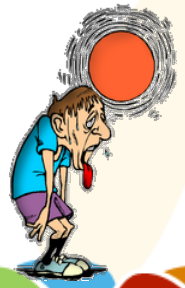


Our world is warming




- **If you are 29 years old, you have never experienced a colder-than-average month in your life!**

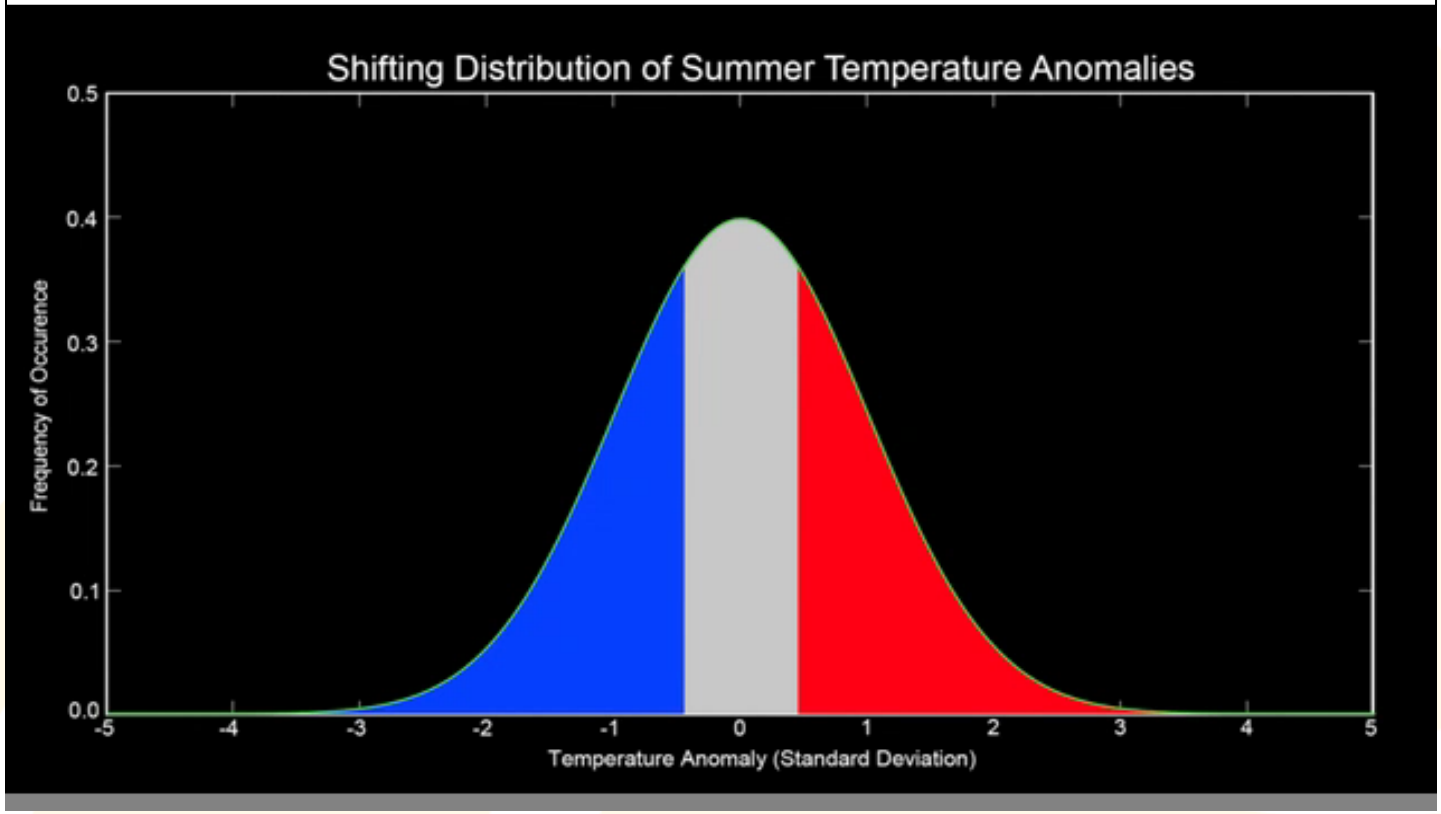


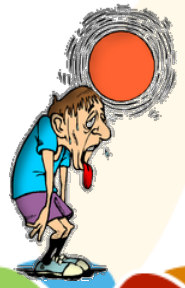


Our world is warming



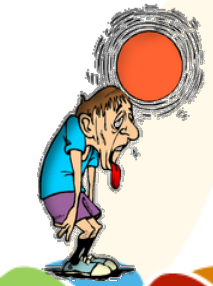

Shift in northern hemisphere summer temperature anomalies
(1950-2011, all weather stations)



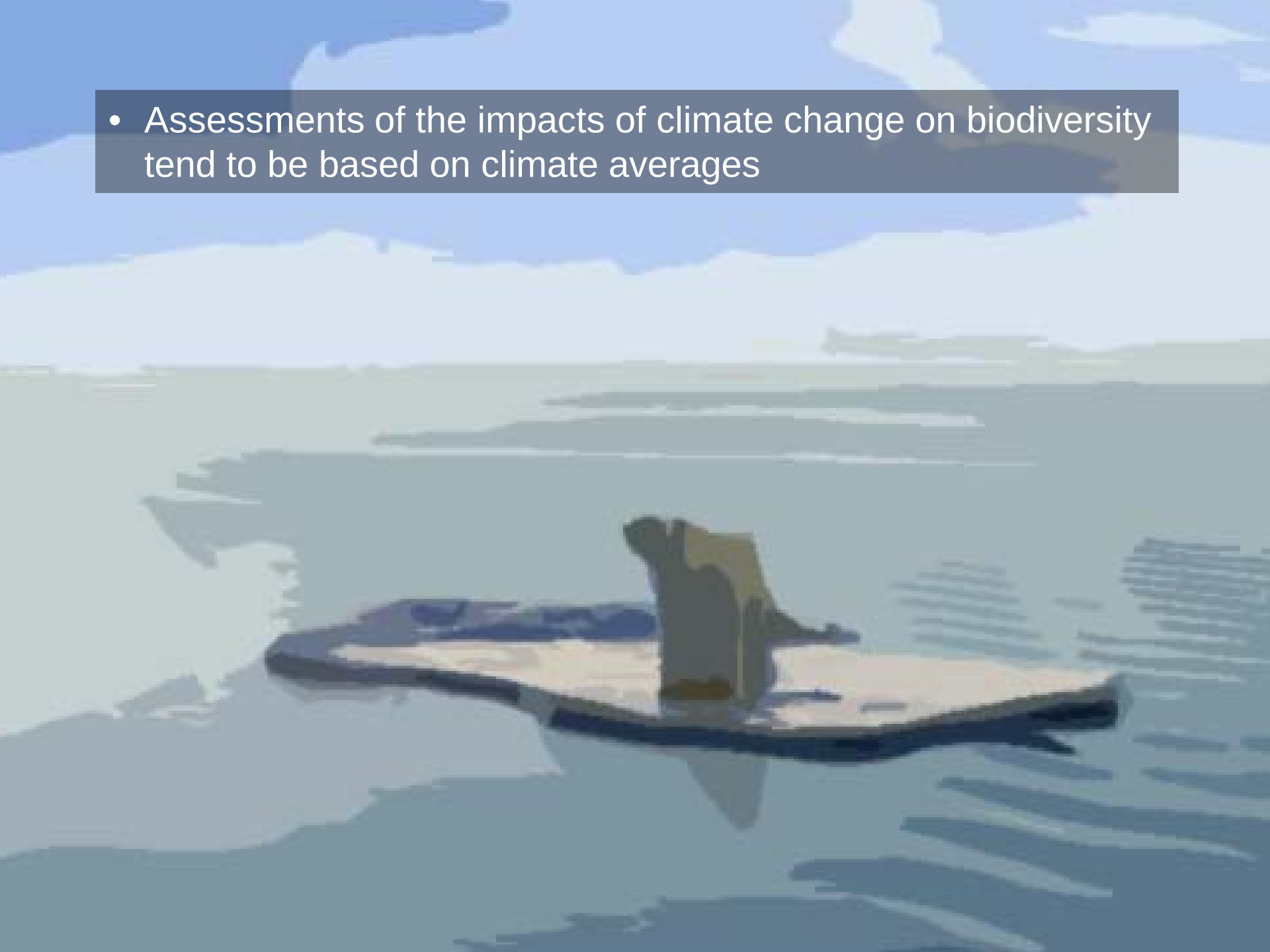


Hansen et al. 2012 PNAS 109: E2415-2423

What are the impacts of such extreme events on biodiversity?

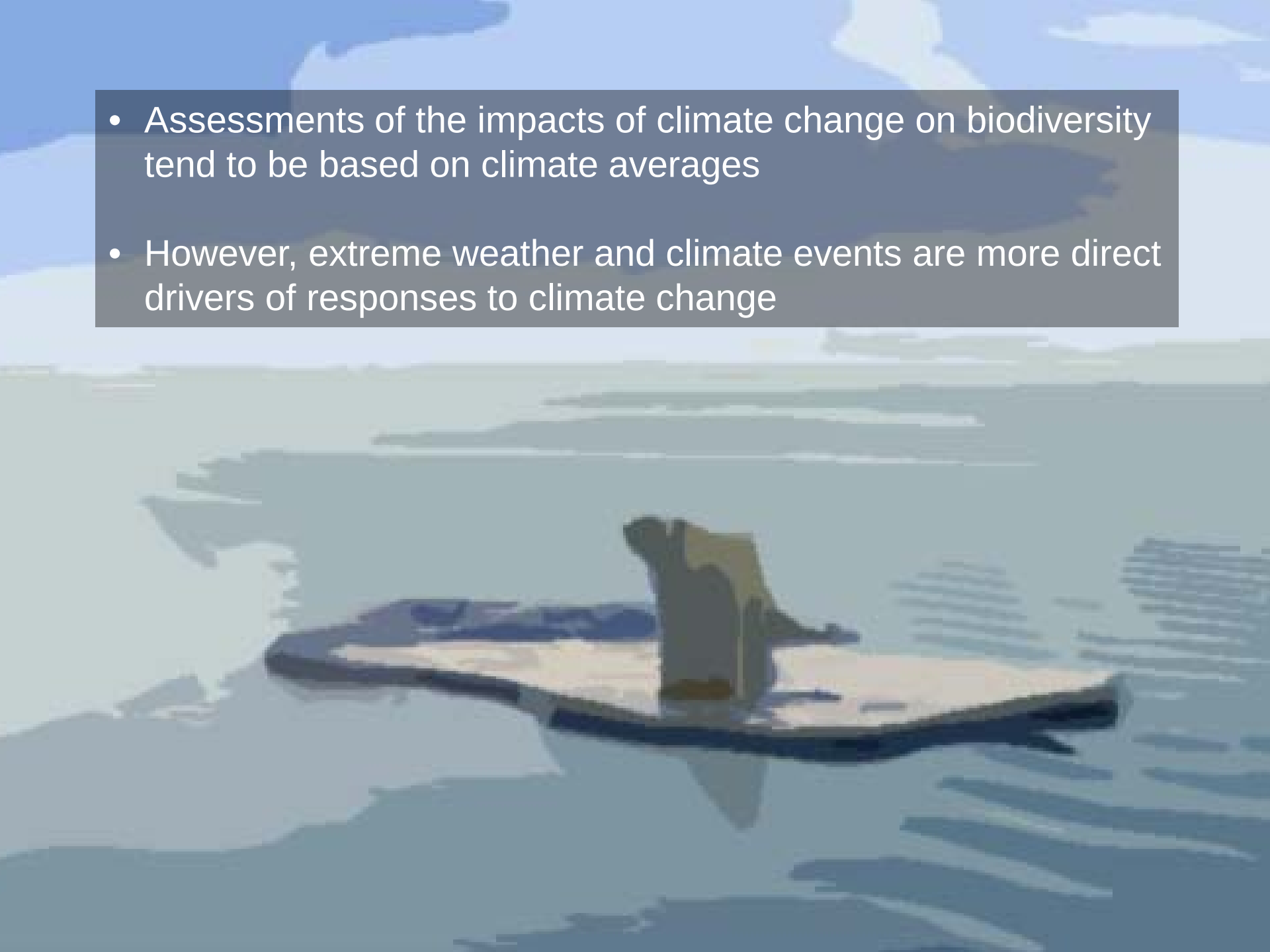


- Assessments of the impacts of climate change on biodiversity tend to be based on climate averages

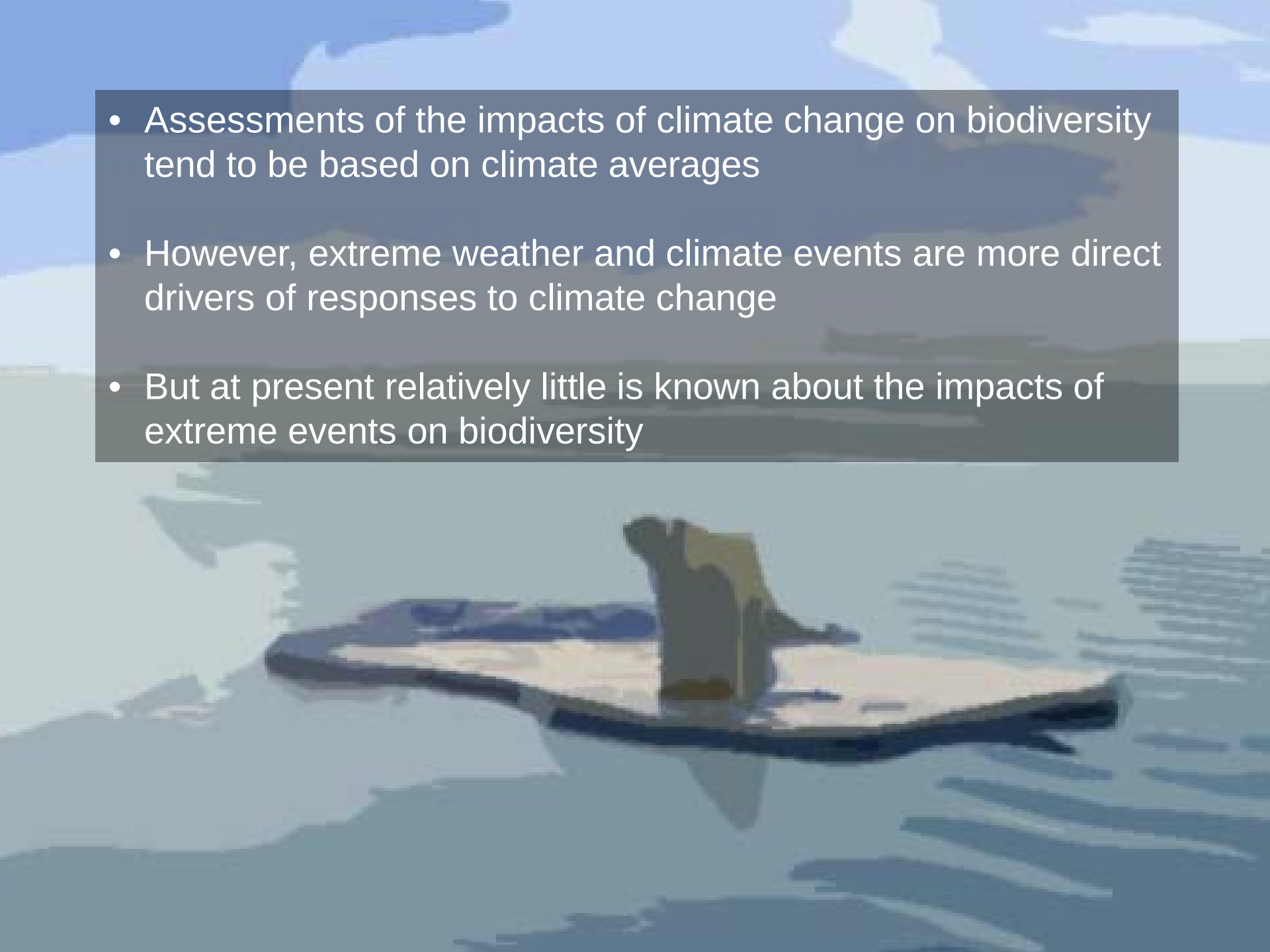


- Assessments of the impacts of climate change on biodiversity tend to be based on climate averages

- However, extreme weather and climate events are more direct drivers of responses to climate change

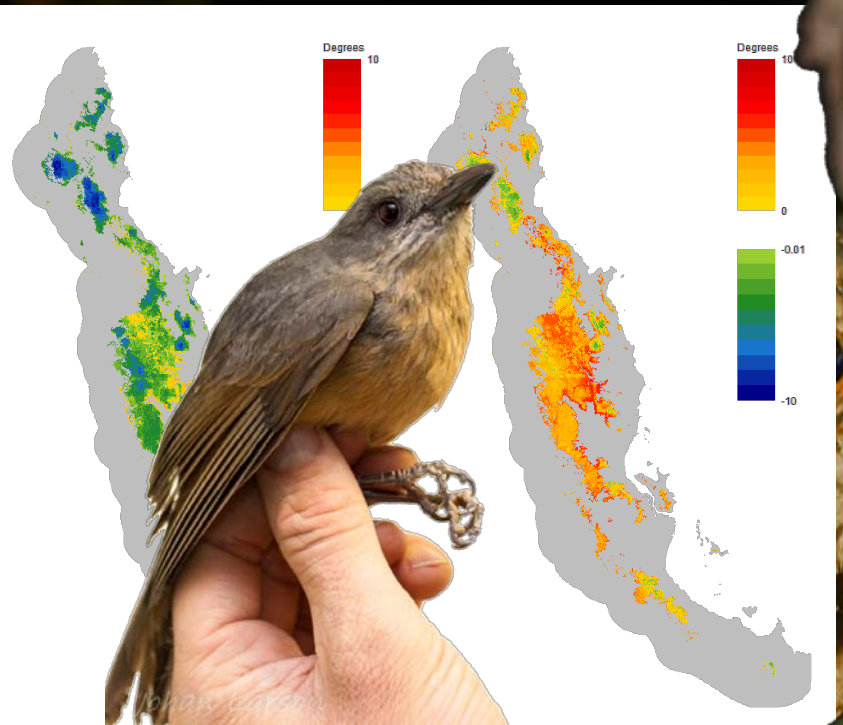


- Assessments of the impacts of climate change on biodiversity tend to be based on climate averages
- However, extreme weather and climate events are more direct drivers of responses to climate change
- But at present relatively little is known about the impacts of extreme events on biodiversity



The vulnerability of Australia's Wet Tropics biodiversity to extreme temperature events

Justin Welbergen, Andrew Krockenberger, Jeremy VanDerWal, Collin Storlie, Jessica Meade, Anastasia Dalziell, Lauren Hodgson, Johan Larson, Luke Shoo, Steve Williams




Wet Tropics Bioregion

Wet Tropics Bioregion

- Is arguably the world's best understood tropical 'hotspot'

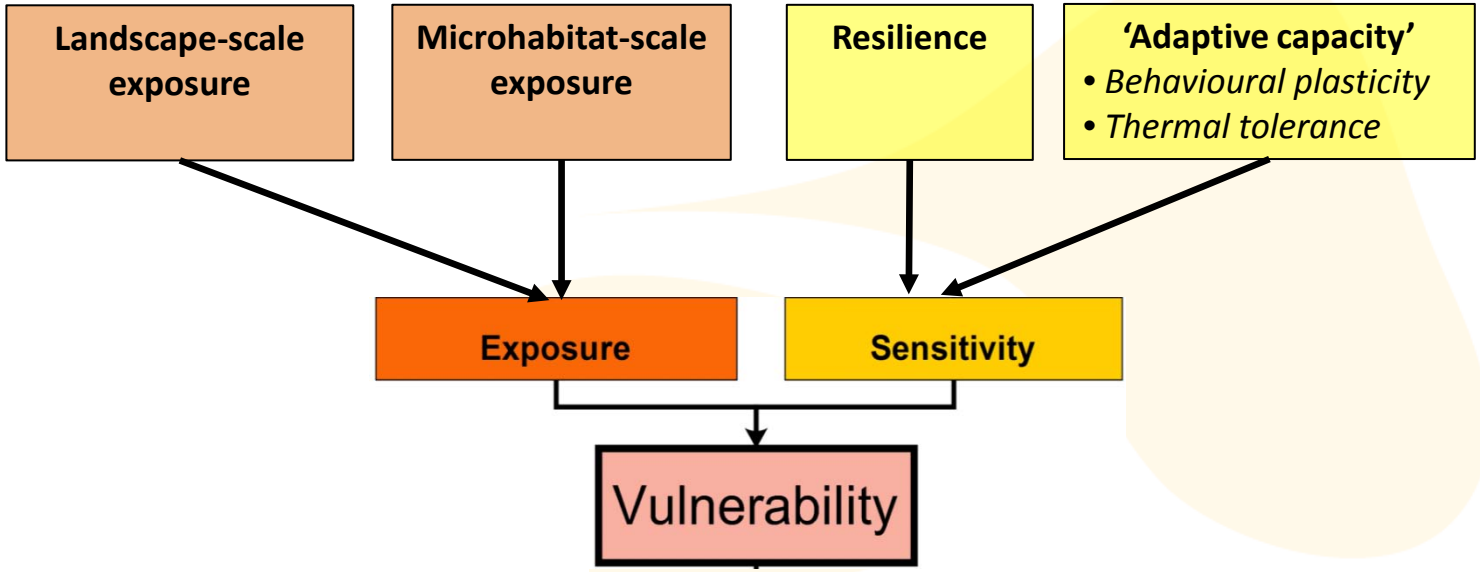
Wet Tropics Bioregion

- Is arguably the world's best understood tropical 'hotspot'
- Detailed animal distribution and environmental data have been collected over the last 20+ years (Williams et al; CTBCC)

Wet Tropics Bioregion

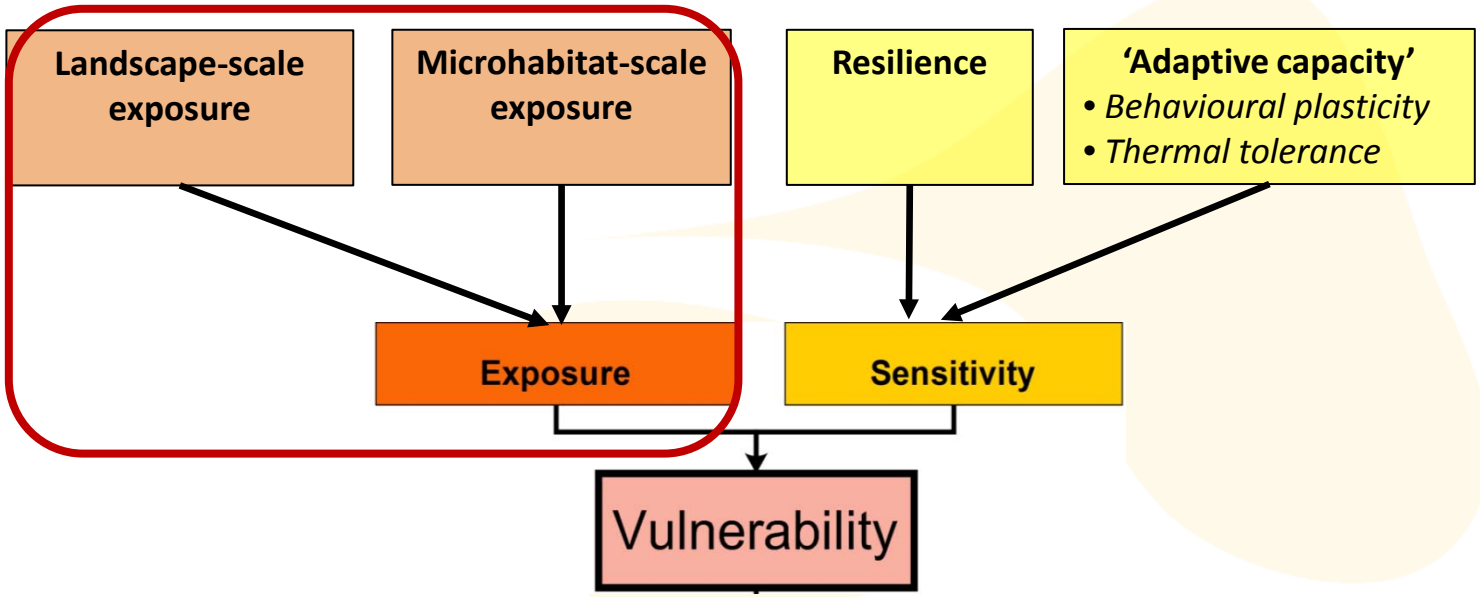
- Is arguably the world's best understood tropical 'hotspot'
- Detailed animal distribution and environmental data have been collected over the last 20+ years (Williams et al; CTBCC)
- This provides a wonderful opportunity for assessing the vulnerability of tropical biodiversity to extreme events

Assessing vulnerability of biodiversity to extreme events



Based on Williams, S.E., Shoo, L.P., Isaac, J.L., Hoffmann, A.A.& Langham, G. (2008). *PLoS Biol*, 6, 2621-6.

Assessing vulnerability of biodiversity to extreme events



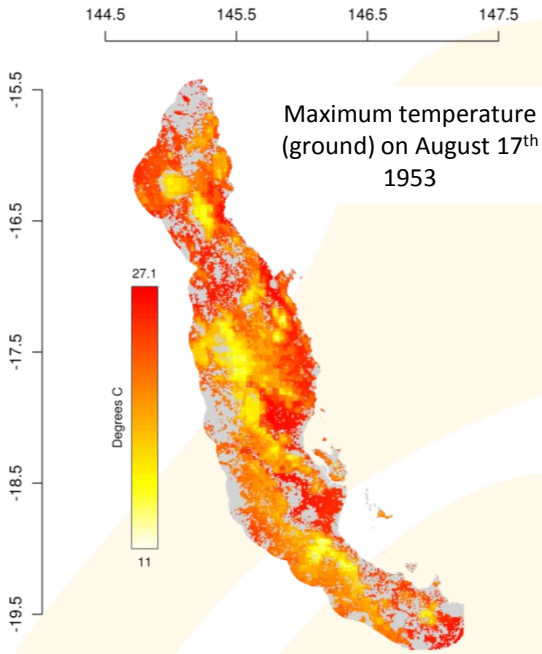
- Outputs year 1: Accurate high-resolution maps of the ***exposure*** to temperature extremes as experienced by organisms in-situ

Based on Williams, S.E., Shoo, L.P., Isaac, J.L., Hoffmann, A.A.& Langham, G. (2008). *PLoS Biol*, 6, 2621-6.

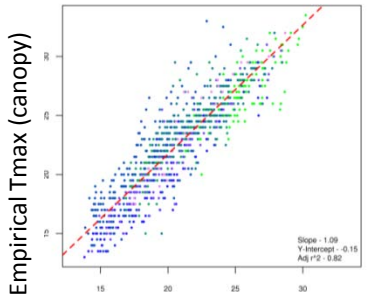
Exposure

- Year 1: Accurate high-resolution maps of the ***exposure*** to temperature extremes as experienced by organisms in-situ

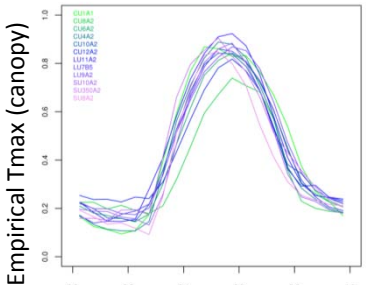
Downscaled estimates of historical daily maximum and minimum temperature...



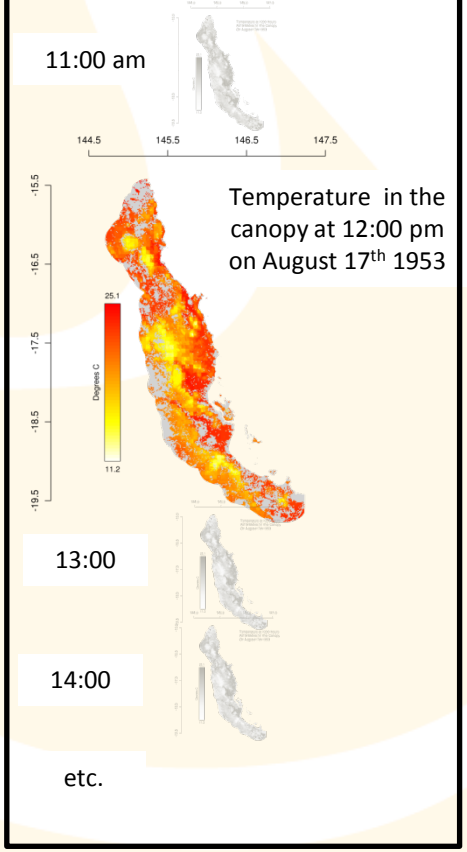
closely predict hourly temperatures in key microhabitats...



+



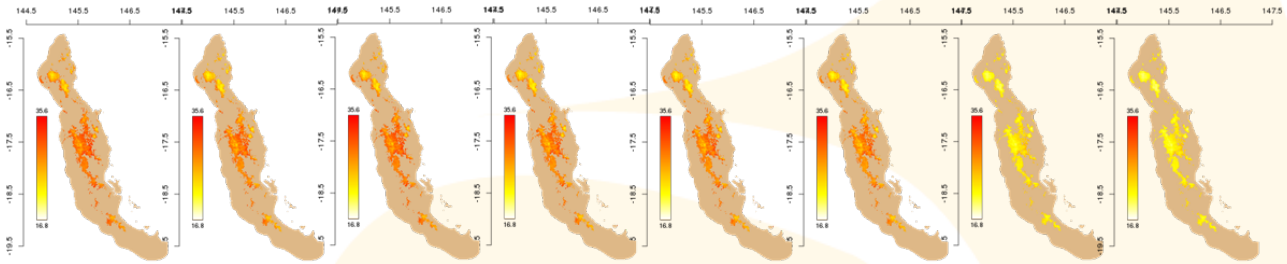
enabling hourly estimates of historical temperature in key microhabitats.

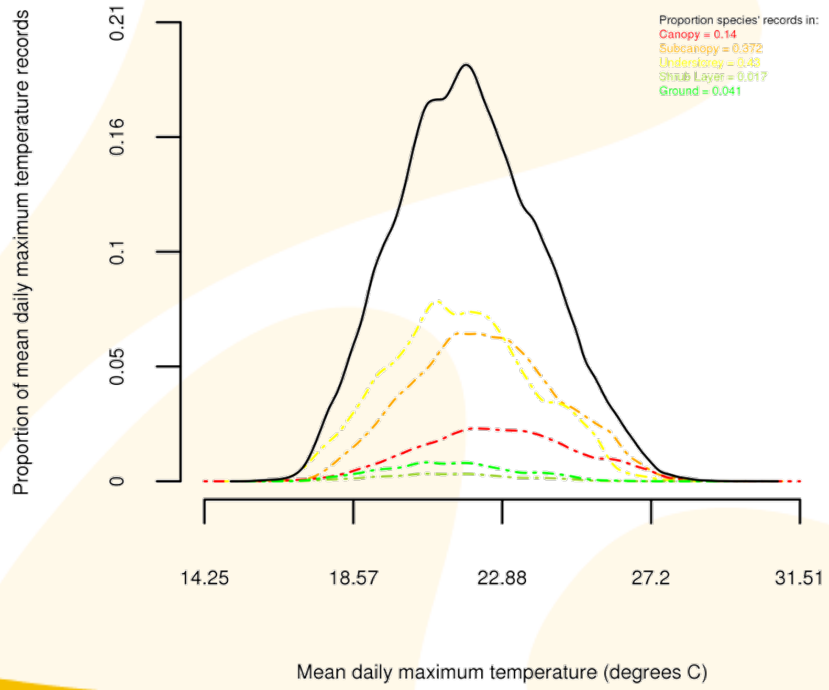


Storlie et al 2013,2014

Exposure

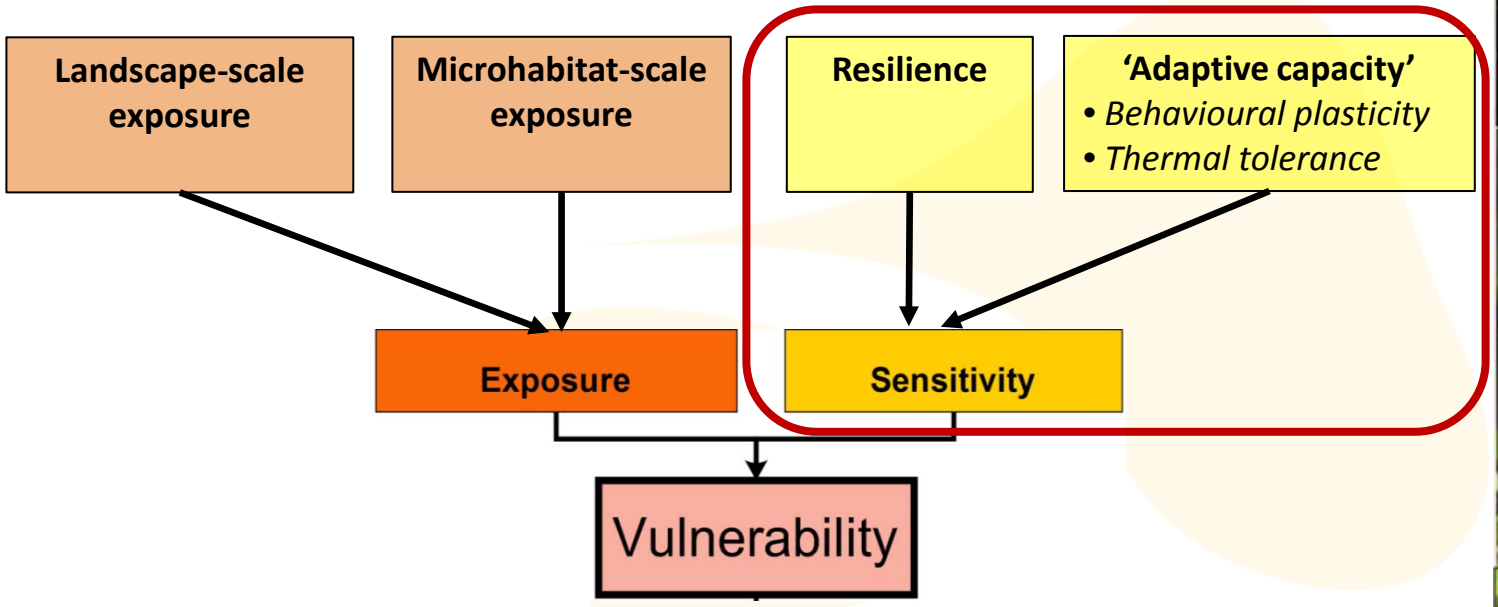
We can now determine the exposure of any species with a known distribution and microhabitat use, to any (hourly) temperature regime





Welbergen et al unpublished

Assessing vulnerability of biodiversity to extreme events



- Outputs year 2: Accurate estimates of the ***sensitivity*** of organisms to temperature extremes

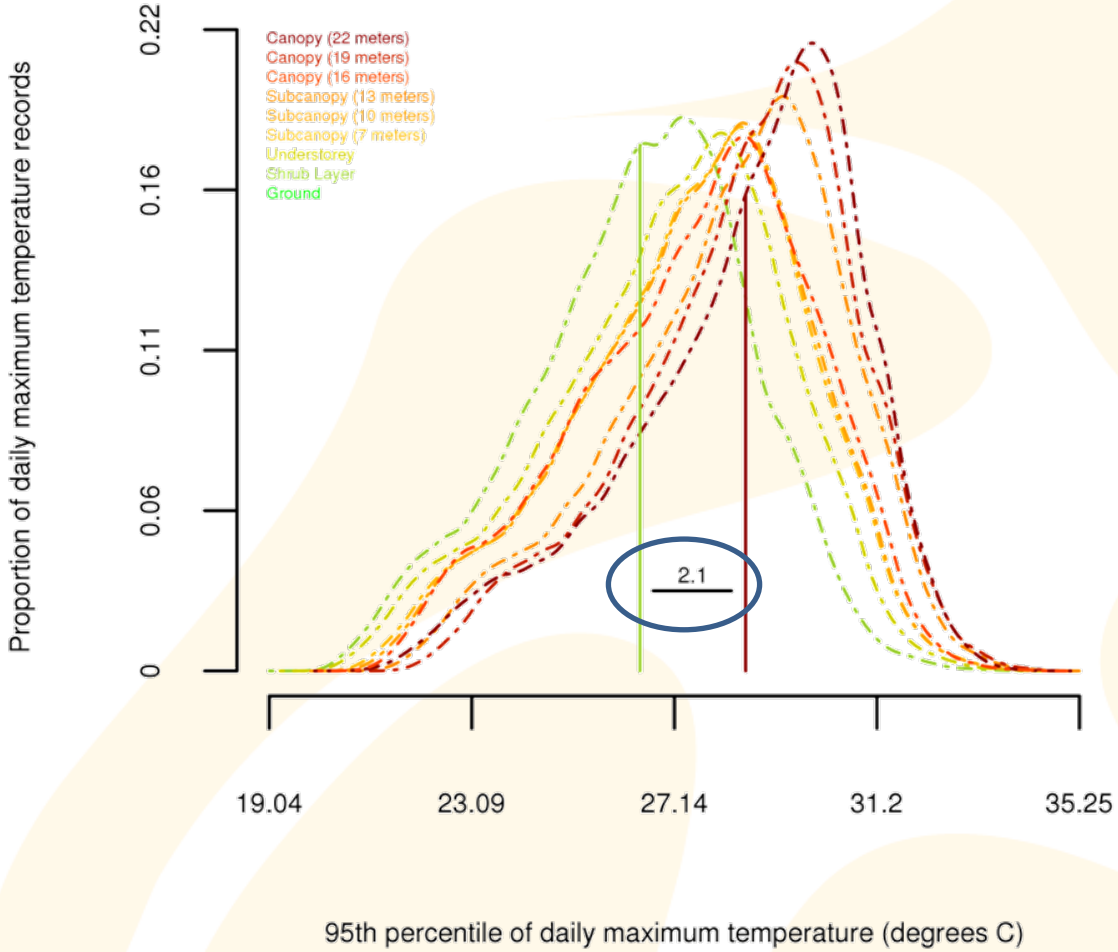
Based on Williams, S.E., Shoo, L.P., Isaac, J.L., Hoffmann, A.A.& Langham, G. (2008). *PLoS Biol*, 6, 2621-6.

We produced a validated index of 'resilience' = the ability of populations to recover from environmental disturbances

Rank	Resilience index	Binomial species' name	Common name	IUCN Status
1	0.000	*Techmarscincus jigurru*	Bartle Frere cool-skink	NL
2	0.001	*Eulamprus frerei*	Bartle Frere barsided skink	NL
3	0.009	*Cophixalus neglectus*	Tangerine nursery-frog	EN B1ab(v)+2ab(v)
4	0.087	*Hemibelideus lemuroides*	Lemuroid ringtail possum	LR NT
5	0.091	*Cophixalus monticola*	Mountain top nursery-frog	EN B1ab(v)+2ab(v)
6	0.100	*Cophixalus hosmeri*	Pipping nursery-frog	VU D2
7	0.103	*Lampropholis robertsi*	Grey-bellied sunskink	NL
8	0.104	*Trichosurus vulpecula johnstonii*	Coppery brushtail possum	LR LC
9	0.105	*Taudactylus rheophilus*	Northern tinkerfrog	CR A2ac; B2ab(v)
10	0.109	*Antechinus godmani*	Atherton antechinus	LR NT
11	0.111	*Saproscincus czechurai*	Saproscincus czechurai	NL
12	0.112	*Sminthopsis leucopus*	White-footed dunnart	DD
13	0.116	*Glaphyromorphus mjobergi*	Atherton Tableland mulch-skink	NL
14	0.120	*Pseudochirulus herbertensis*	Herbert river ringtail possum	LR NT
15	0.123	*Acanthiza katherina*	Mountain thornbill	LC
16	0.123	*Uromys hadrourus*	Masked white-tailed rat	LR NT
17	0.125	*Prionodura newtoniana*	Golden bowerbird	LC
18	0.128	*Ptilonorhynchus violaceus*	Satin bowerbird	LC
19	0.128	*Dasyurus maculatus*	Spotted-tailed quoll	VU C1+2a
20	0.130	*Sericornis keri*	Atherton scrubwren	LC

Welbergen et al, unpublished

We quantified ‘behavioural plasticity’ = the ability of species to seek out cooler microhabitats

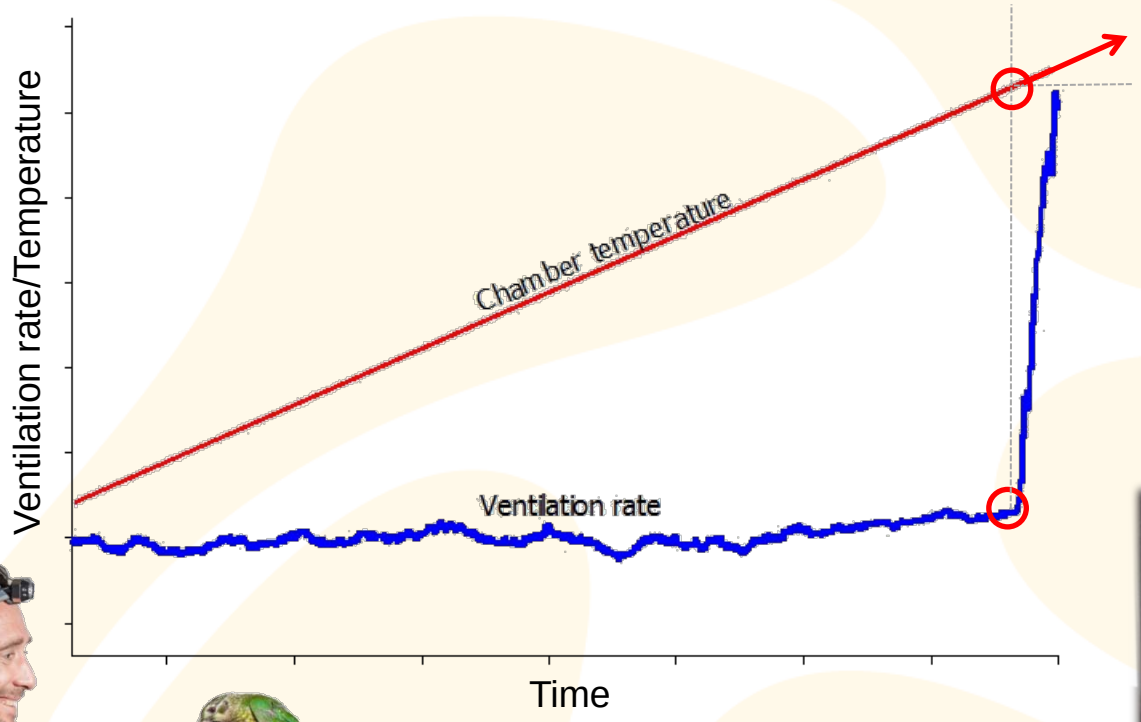


Welbergen et al unpublished

We quantified ‘thermotolerance’ (= the ability of species to withstand certain temperatures) for a wide range of species

We quantified ‘thermotolerance’ (= the ability of species to withstand certain temperatures) for a wide range of species

- Experimentally determined the relationship of ambient temperature versus body temperature & ventilation rate in 60 bird and mammal species from across the Wet Tropics

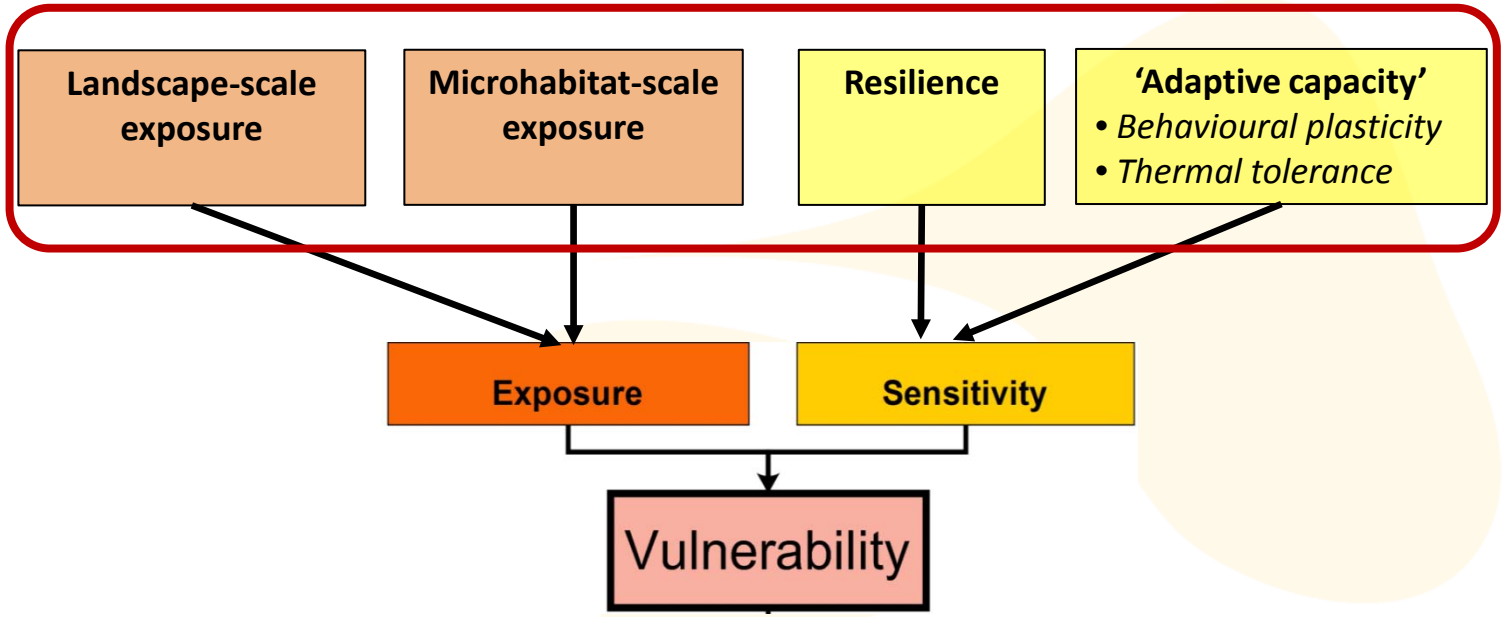


We quantified ‘thermotolerance’ (= the ability of species to withstand certain temperatures) for a wide range of species

- Experimentally determined the relationship of ambient temperature versus body temperature & ventilation rate in 60 bird and mammal species from across the Wet Tropics

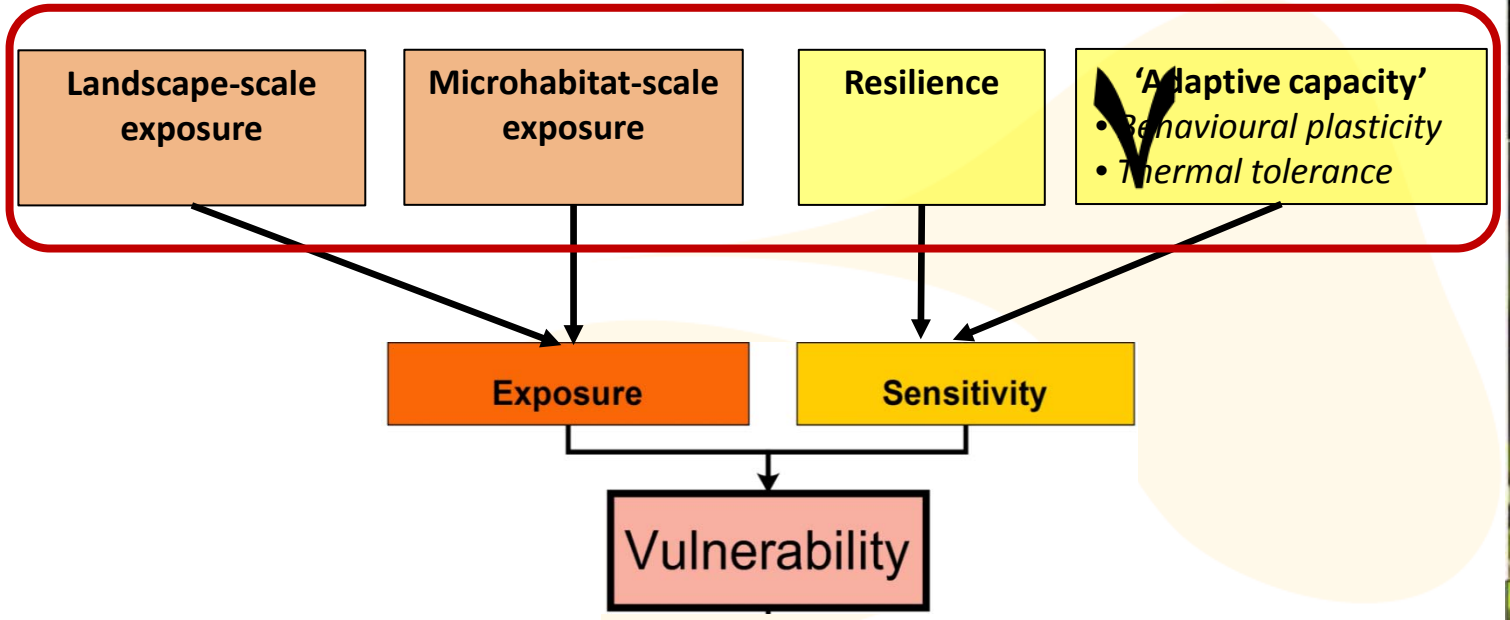
- Literature provided useful data for another 30 ectotherms (reptiles, amphibians)

Assessing vulnerability of biodiversity to extreme events



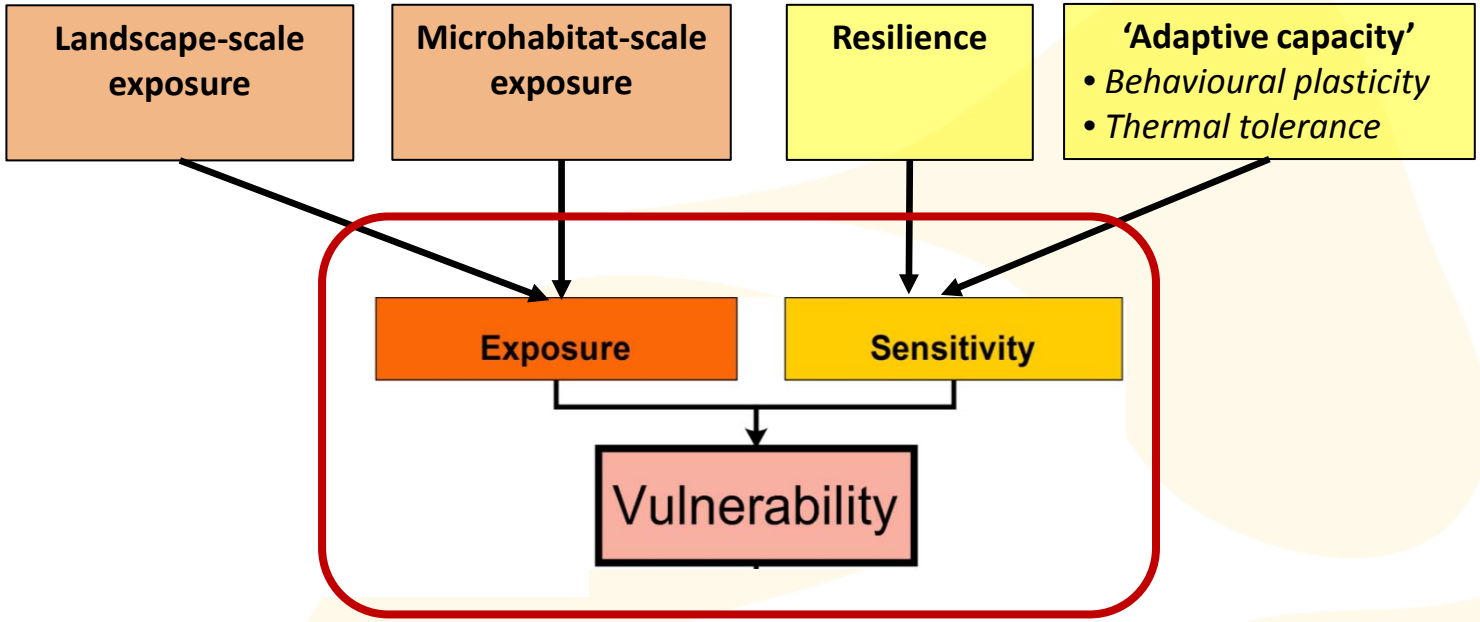
Based on Williams, S.E., Shoo, L.P., Isaac, J.L., Hoffmann, A.A.& Langham, G. (2008). *PLoS Biol*, 6, 2621-6.

Assessing vulnerability of biodiversity to extreme events



Based on Williams, S.E., Shoo, L.P., Isaac, J.L., Hoffmann, A.A.& Langham, G. (2008). *PLoS Biol*, 6, 2621-6.

Assessing vulnerability of biodiversity to extreme events

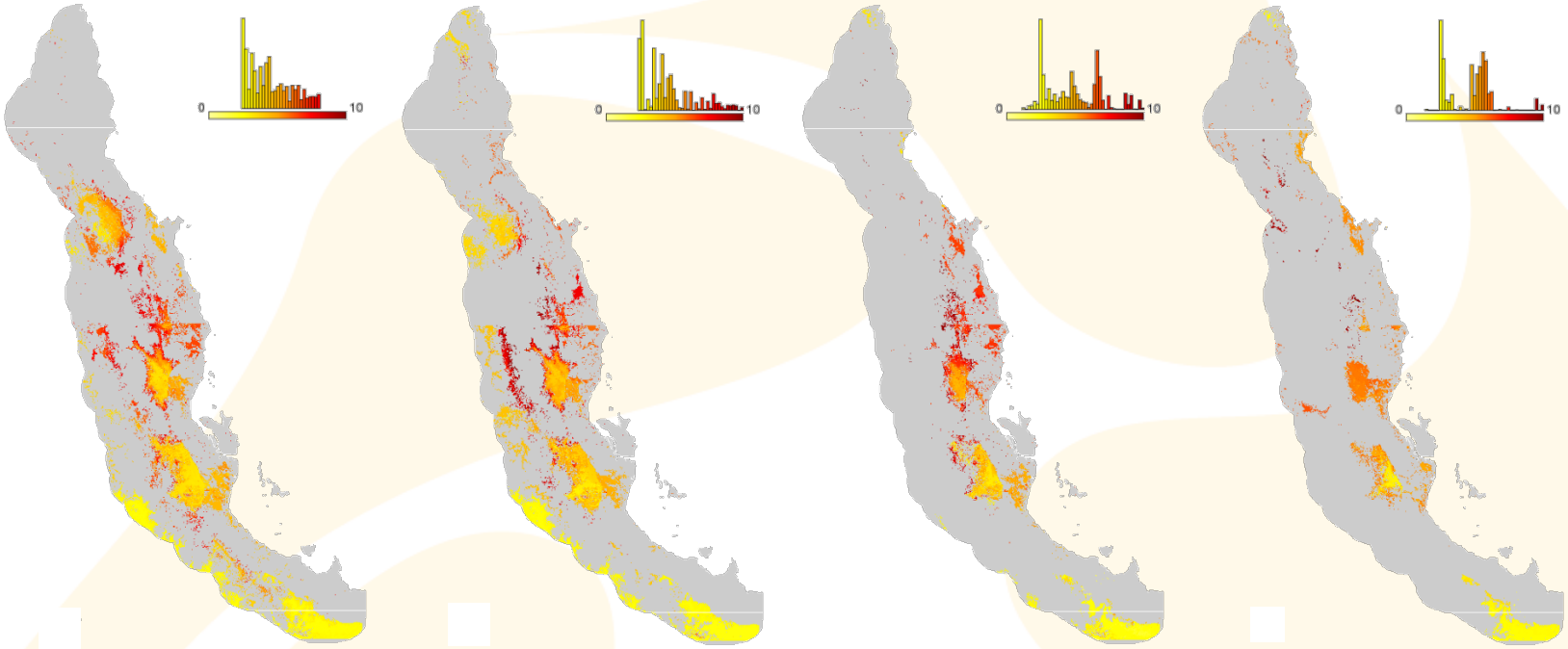


- Outputs year 3: Identification of the areas where biodiversity is most and least vulnerable to temperature extremes (thermal 'hotspots' and 'refugia')

Based on Williams, S.E., Shoo, L.P., Isaac, J.L., Hoffmann, A.A.& Langham, G. (2008). *PLoS Biol*, 6, 2621-6.

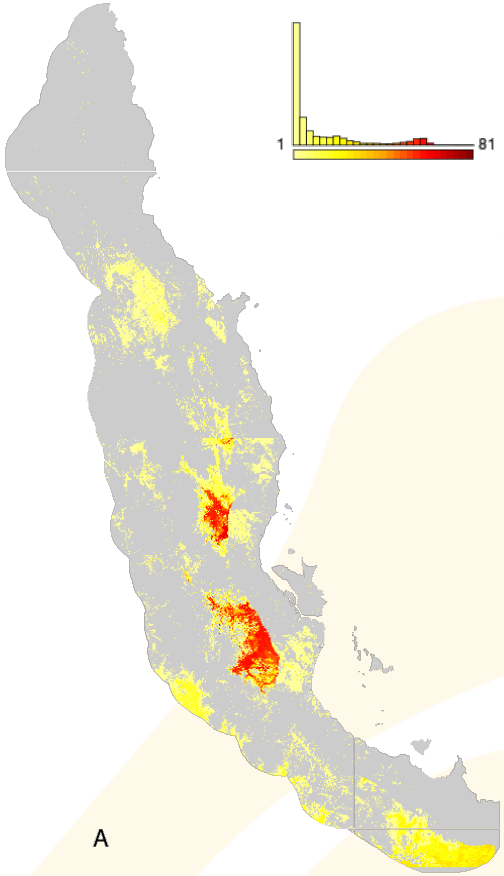
Vulnerability

By combining our information on exposure and sensitivity we can produce maps of the areas where biodiversity is currently *most* vulnerable to temperature extremes ('current thermal hotspots')



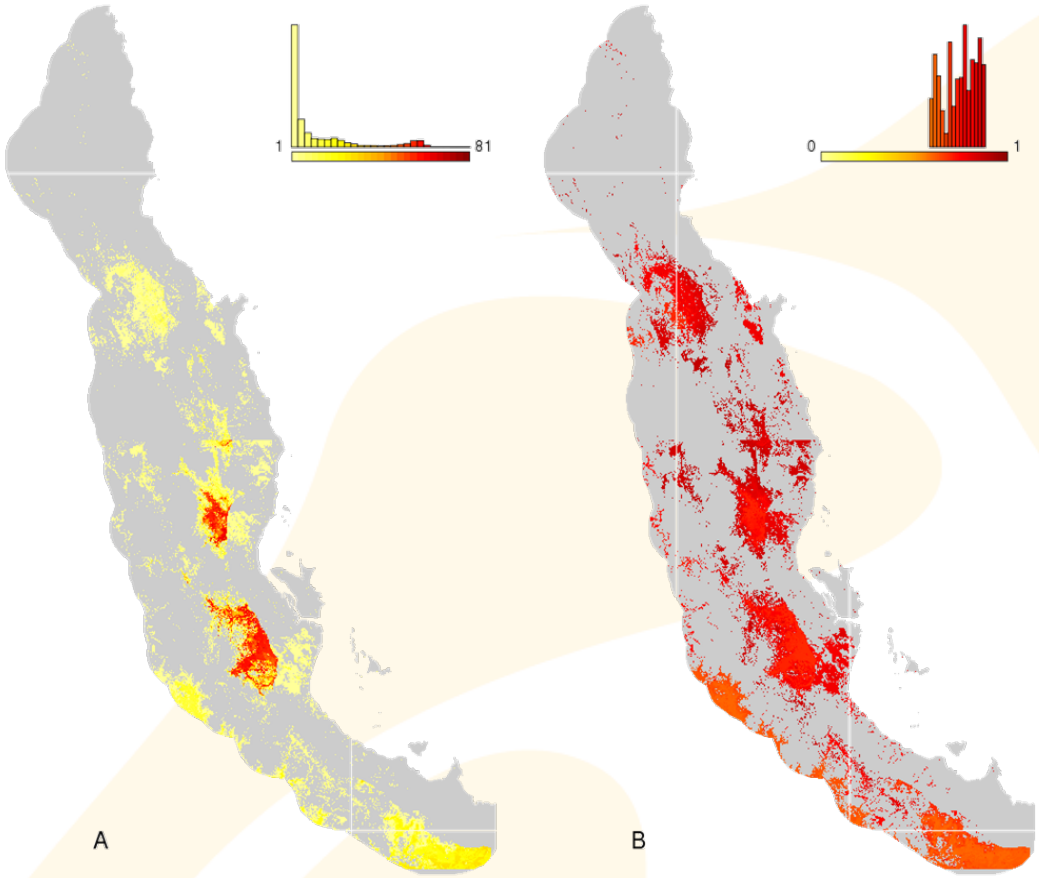
Birds Mammals Reptiles Amphibians

Vulnerability



exposed species

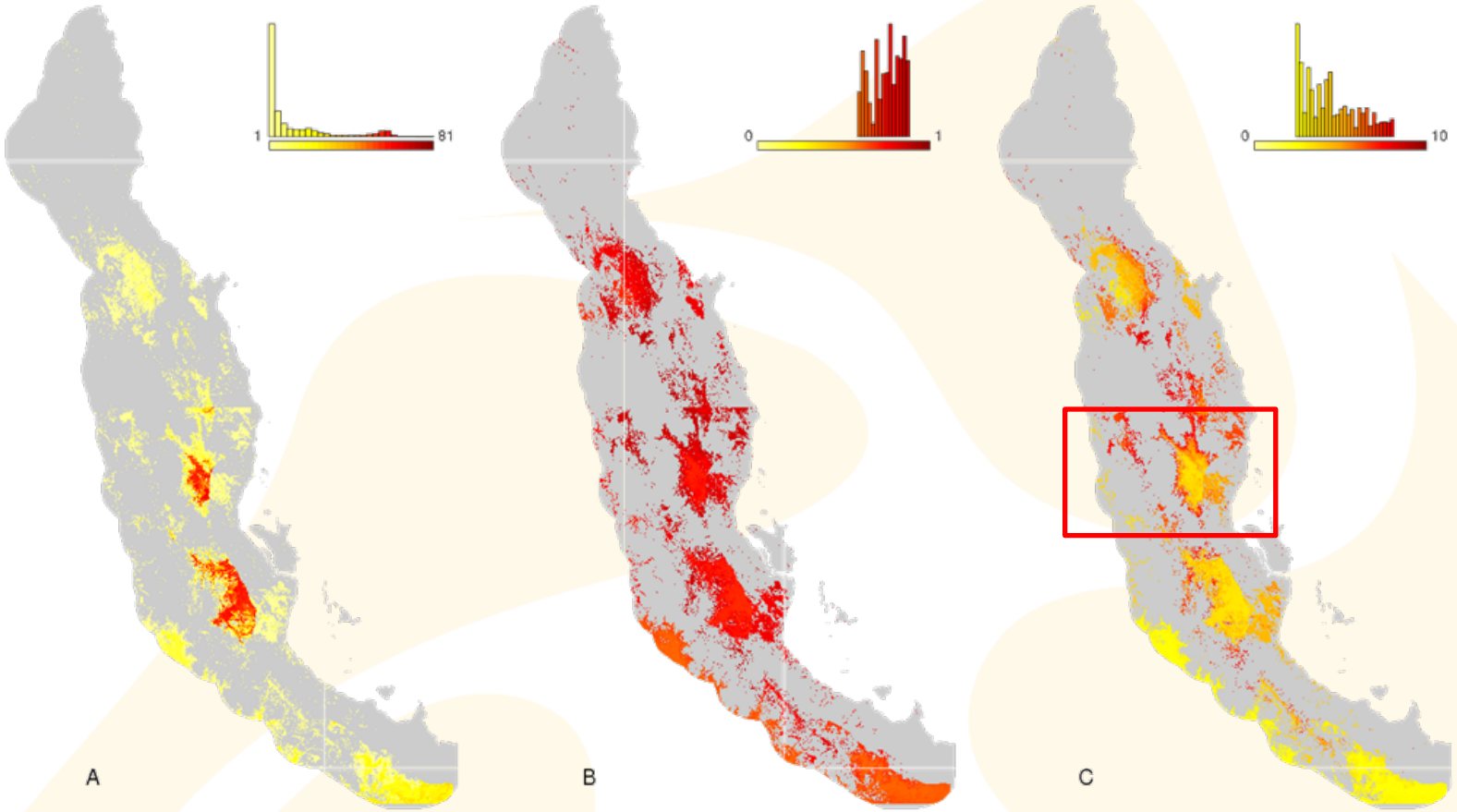
Vulnerability



exposed species

1/x̄ resilience of exposed species

Vulnerability

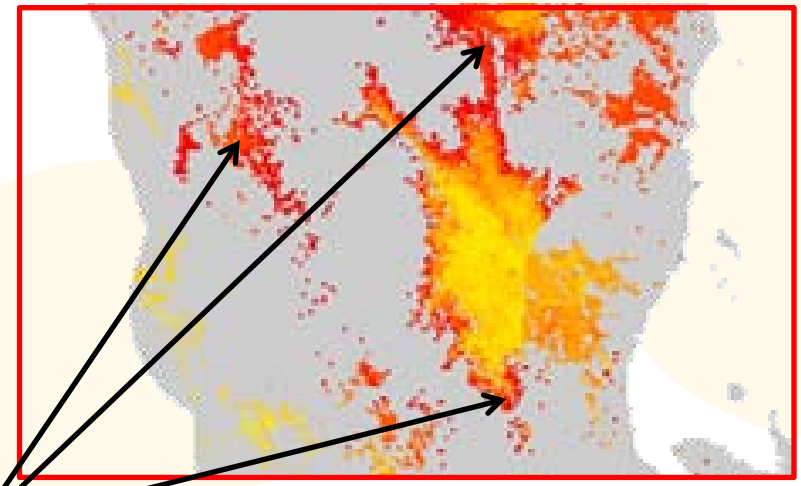


exposed species

1/x̄ resilience of exposed species

thermal hotspots = A/(A*B)

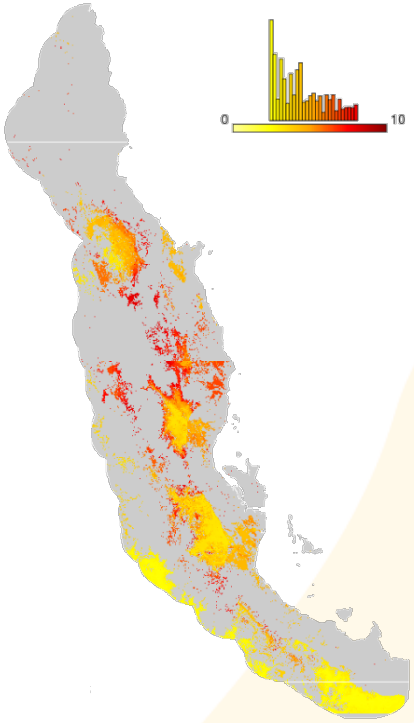
Vulnerability



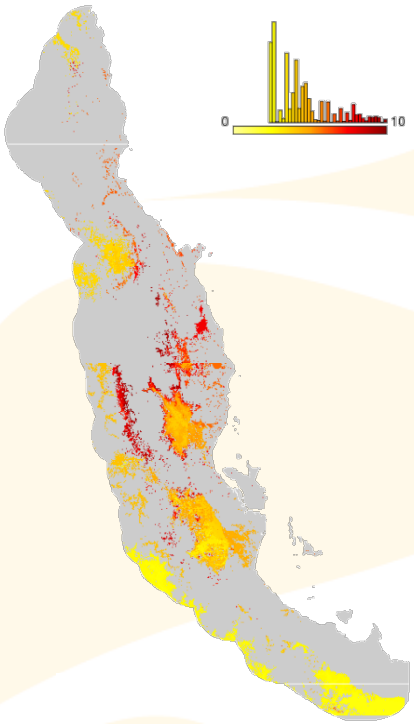
Thermal hotspots:

Areas with the *highest* number of species with the *lowest* mean resilience

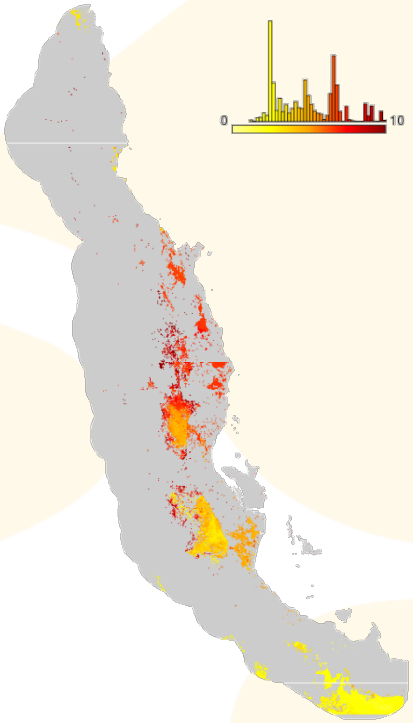
Vulnerability



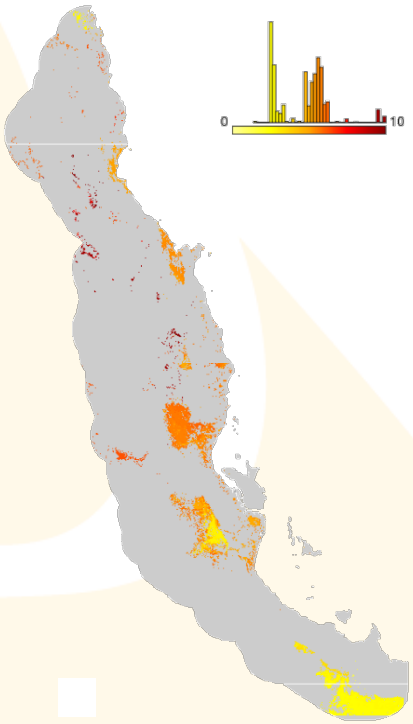
Birds



Mammals

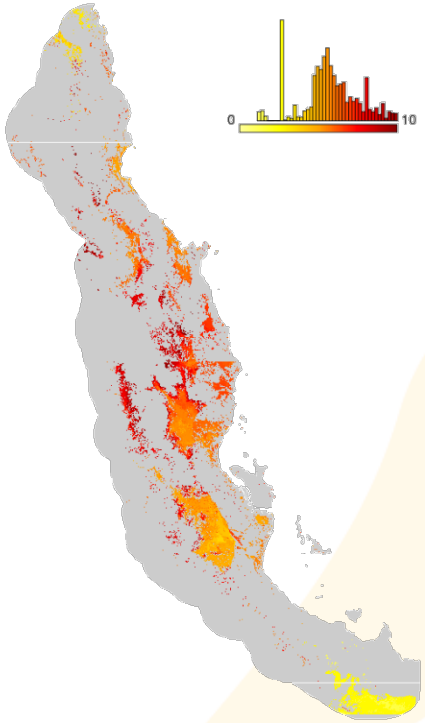


Reptiles

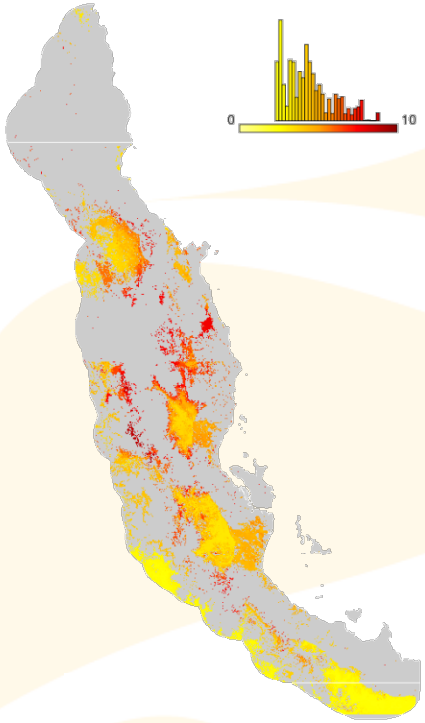


Amphibians

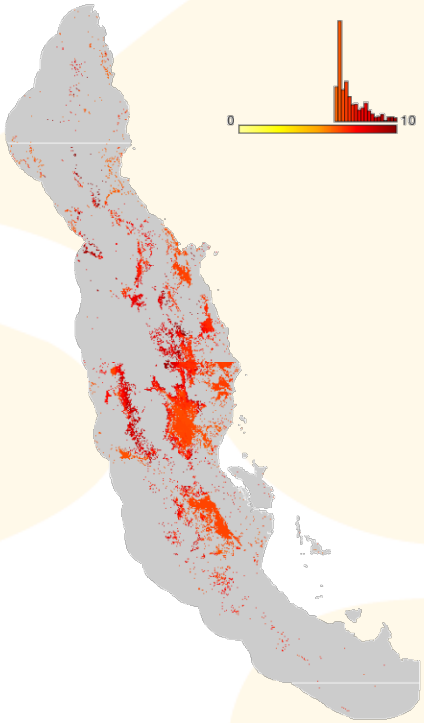
Vulnerability



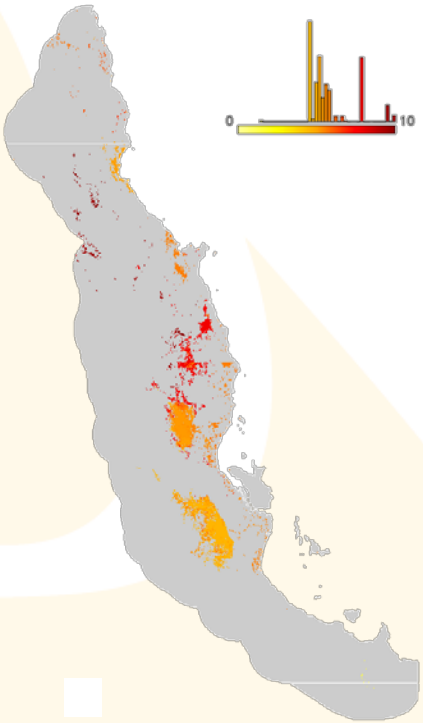
Endemics



Non-endemics



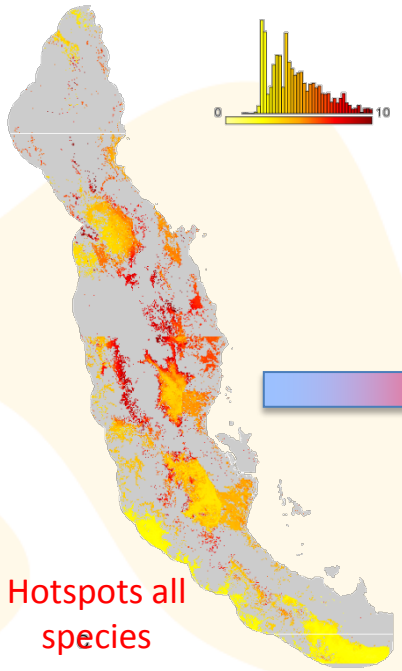
25% Least resilient species



Listed as ‘Near Threatened’ or worse

Vulnerability

- The current thermal hotspots are expected to change significantly in the future

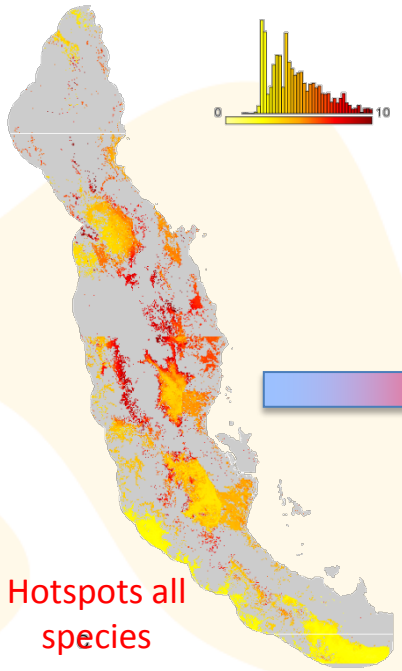


Future?

Hotspots all species

Vulnerability

- The current thermal hotspots are expected to change significantly in the future
  - limits their usefulness for long-term conservation management.

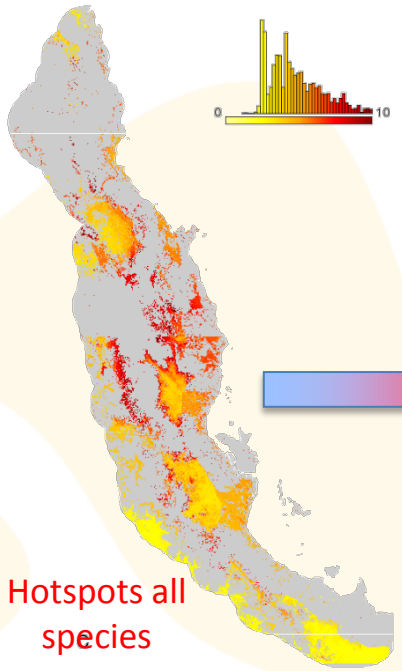


Future?

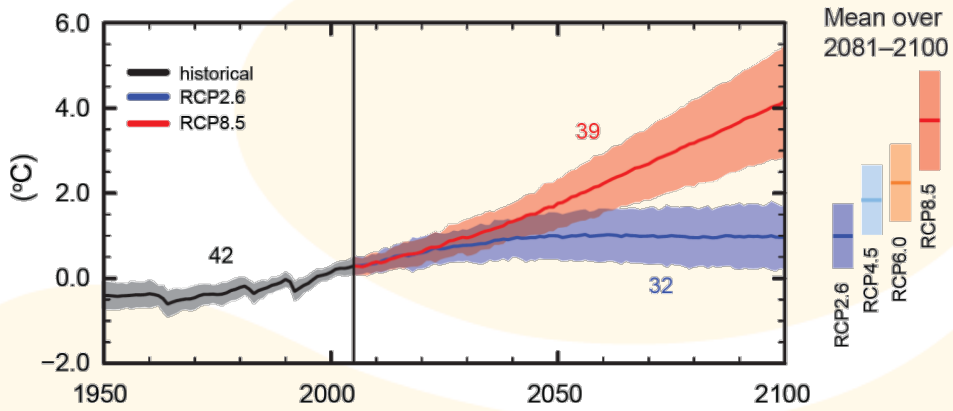
Hotspots all species

Vulnerability

- The current thermal hotspots are expected to change significantly in the future
  - limits their usefulness for long-term conservation management.
- Thus, we need to define the *future* thermal hotspots under a range of climate change scenarios

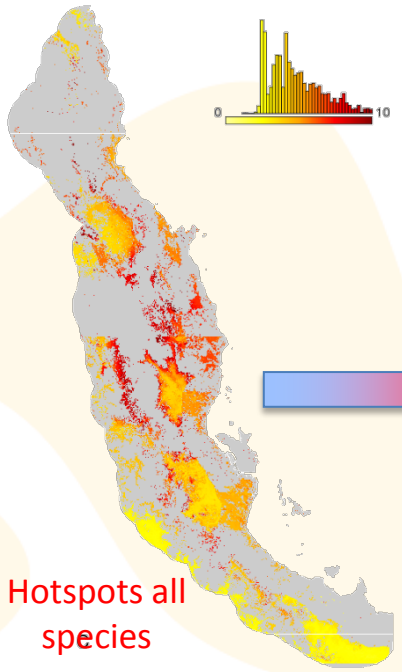


Future?

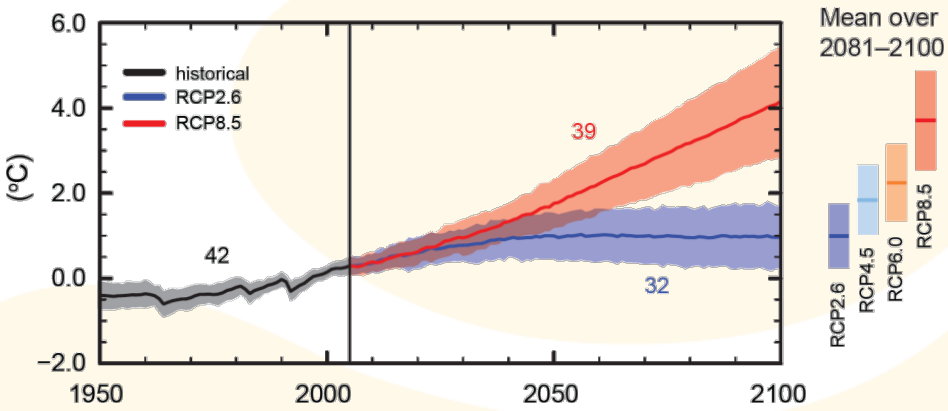


Vulnerability

- The current thermal hotspots are expected to change significantly in the future
  - limits their usefulness for long-term conservation management.
- Thus, we need to define the *future* thermal hotspots under a range of climate change scenarios
  - essential for prioritising conservation actions under climate change.

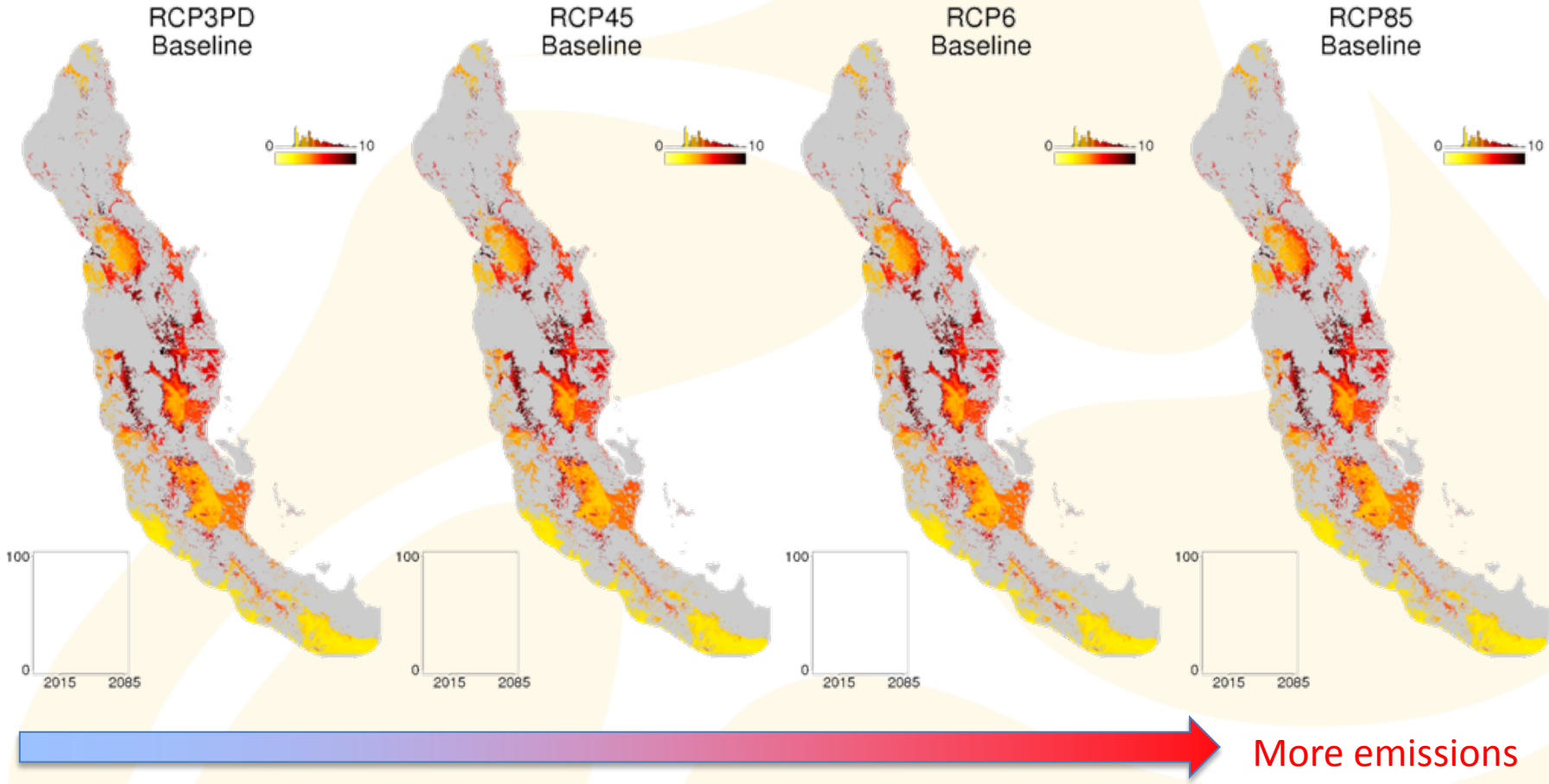


Future?



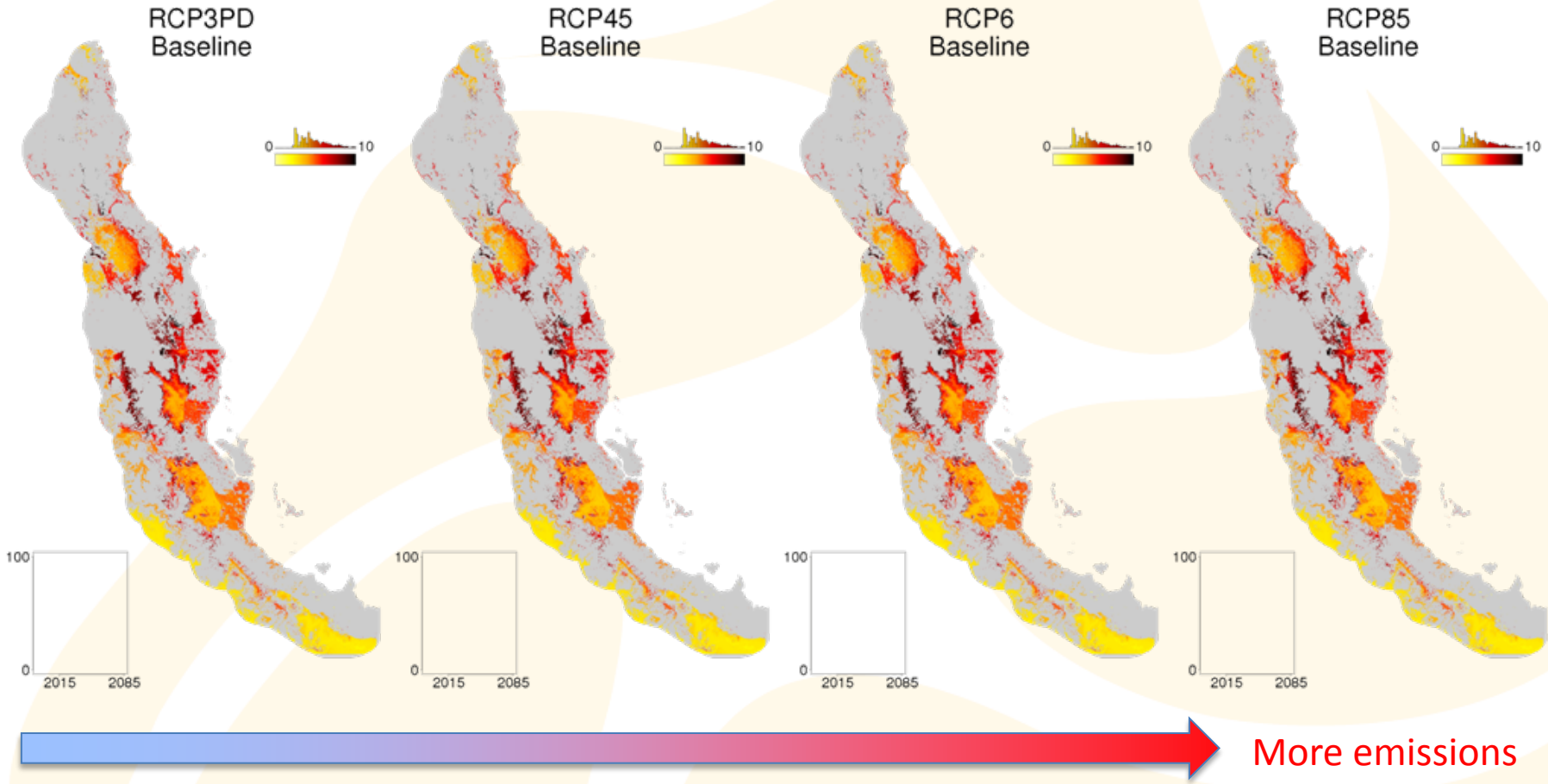
Vulnerability

Future projections of thermal hotspots under different climate change scenarios (4 RCPs, 18 GCMs; 8 time steps between 2015 and 2085; 250m resolution; VanDerWal et al, unpublished)



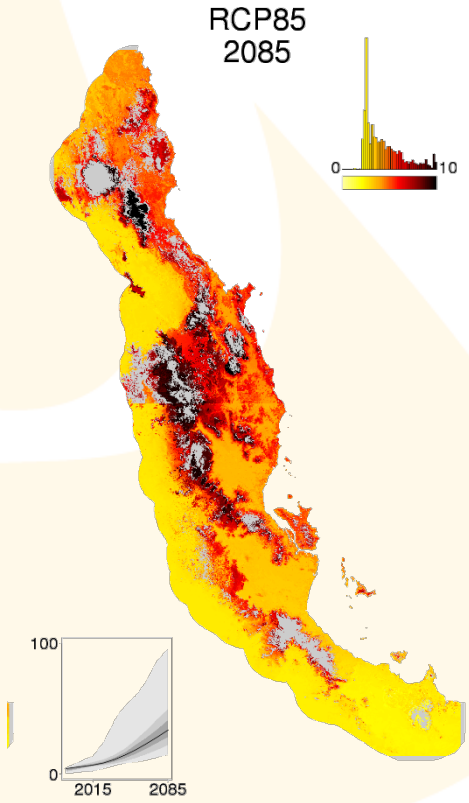
Vulnerability

Future projections of thermal hotspots under different climate change scenarios (4 RCPs, 18 GCMs; 8 time steps between 2015 and 2085; 250m resolution; VanDerWal et al, unpublished)



Vulnerability

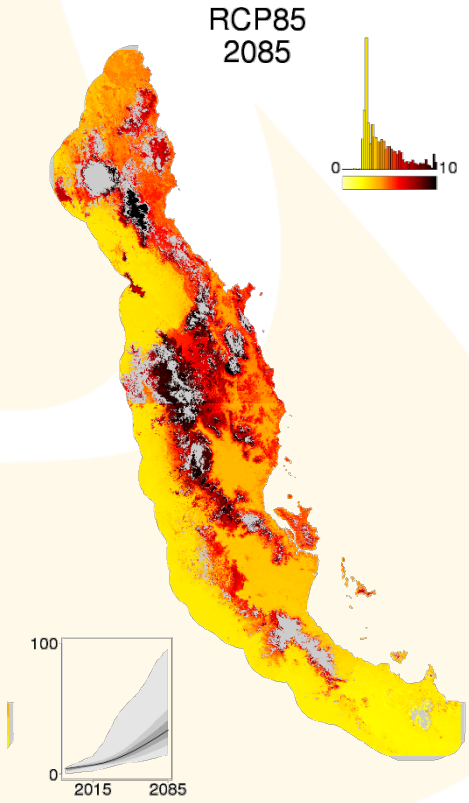
The thermal hotspots are useful for species conservation and habitat restoration management



Vulnerability

The thermal hotspots are useful for species conservation and habitat restoration management

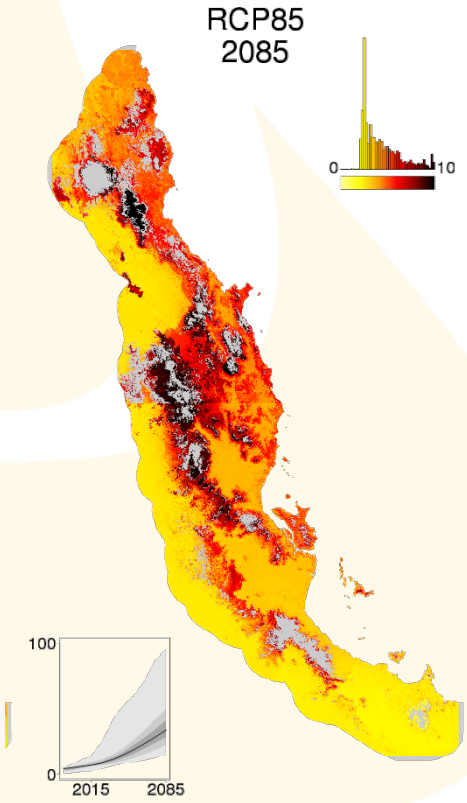
- Areas where species would currently benefit most from habitat restoration (e.g., promotion of cooler microhabitats, including understory and logs)



Vulnerability

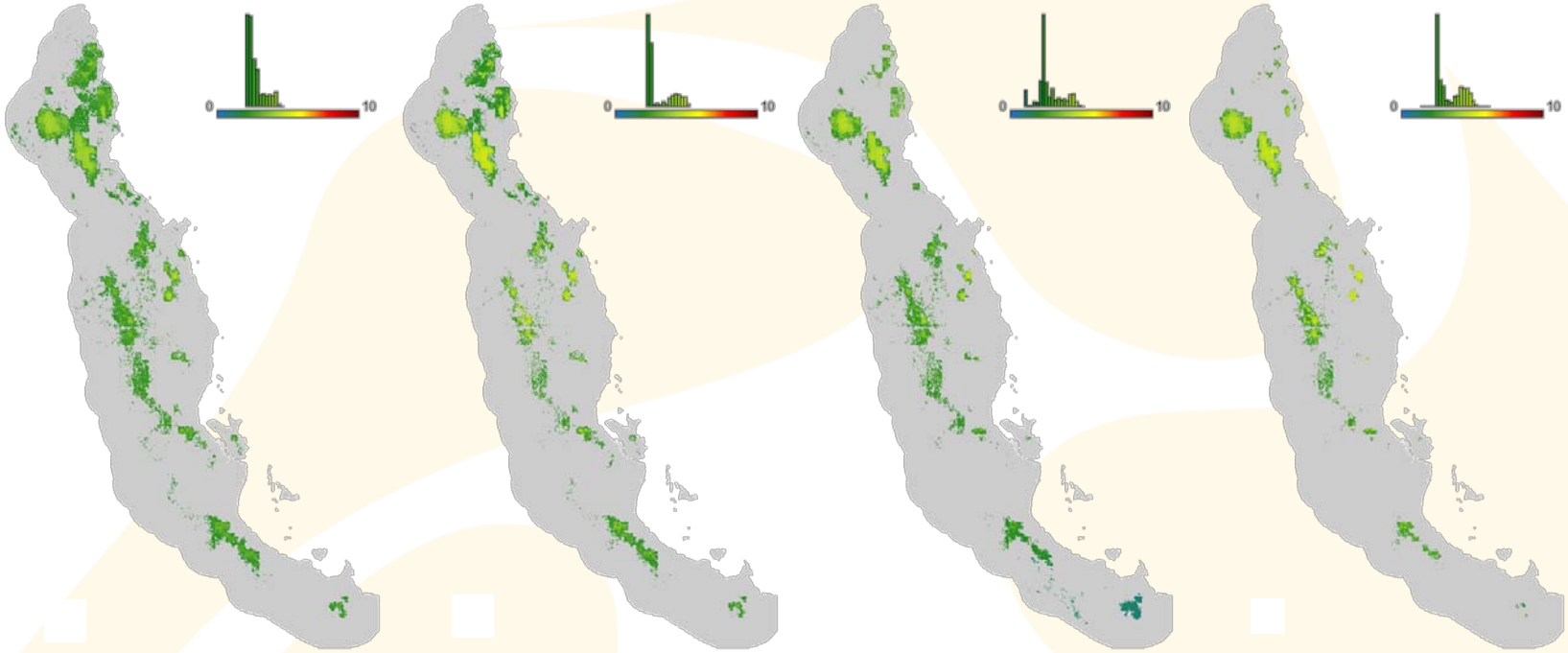
The thermal hotspots are useful for species conservation and habitat restoration management

- Areas where species would currently benefit most from habitat restoration (e.g., promotion of cooler microhabitats, including understory and logs)
- Areas that contain relatively heat-tolerant individuals (i.e., 'locally adapted forms') - targets for species translocations



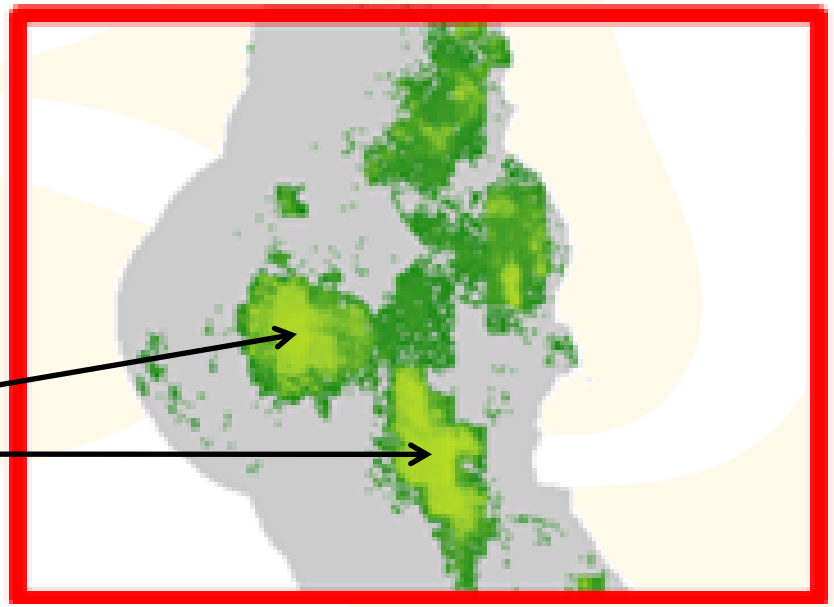
Vulnerability

Conversely, we can also produce maps of the areas where biodiversity is least vulnerable to temperature extremes ('thermal refugia')



Birds Mammals Reptiles Amphibians

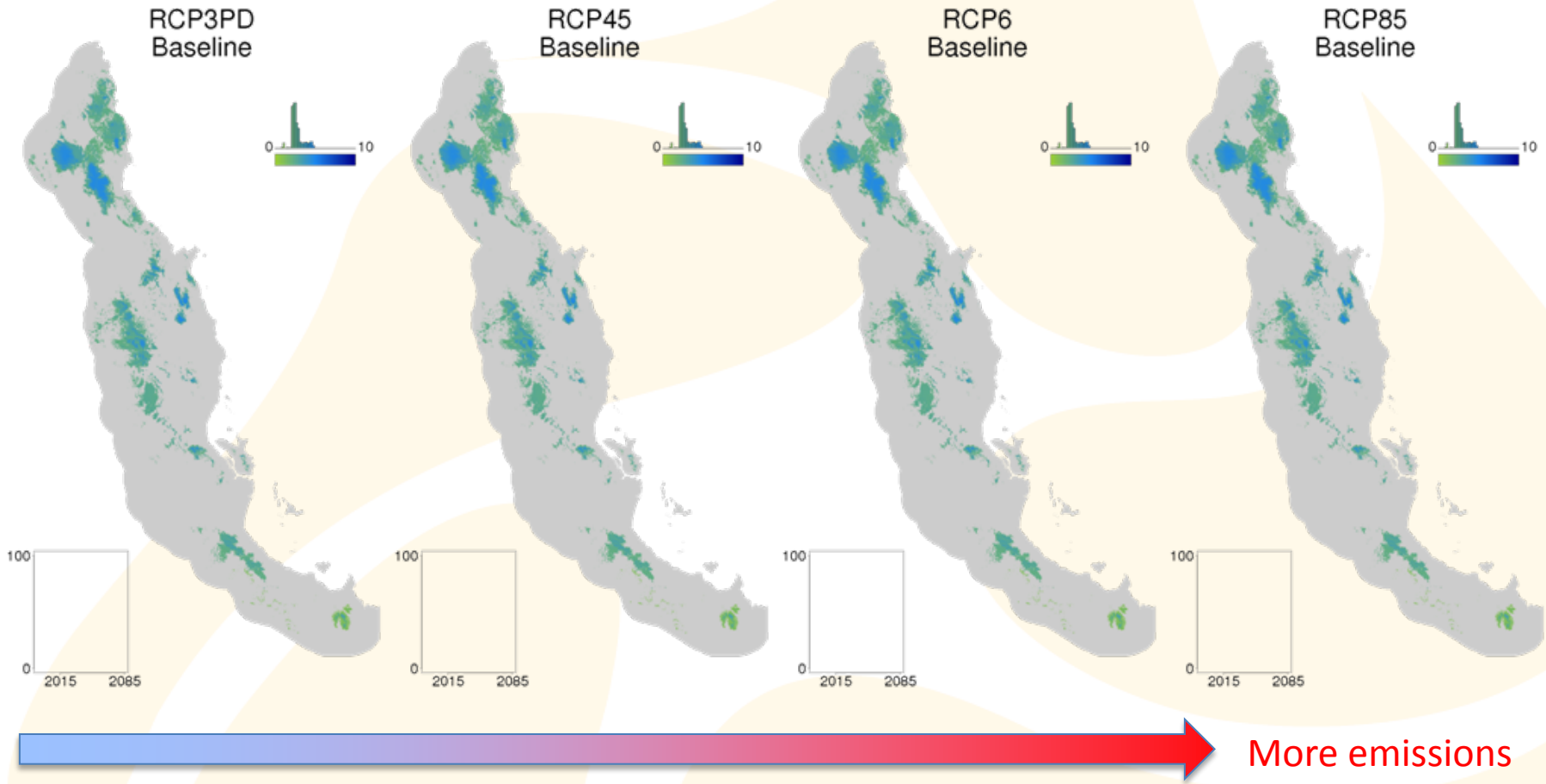
Vulnerability



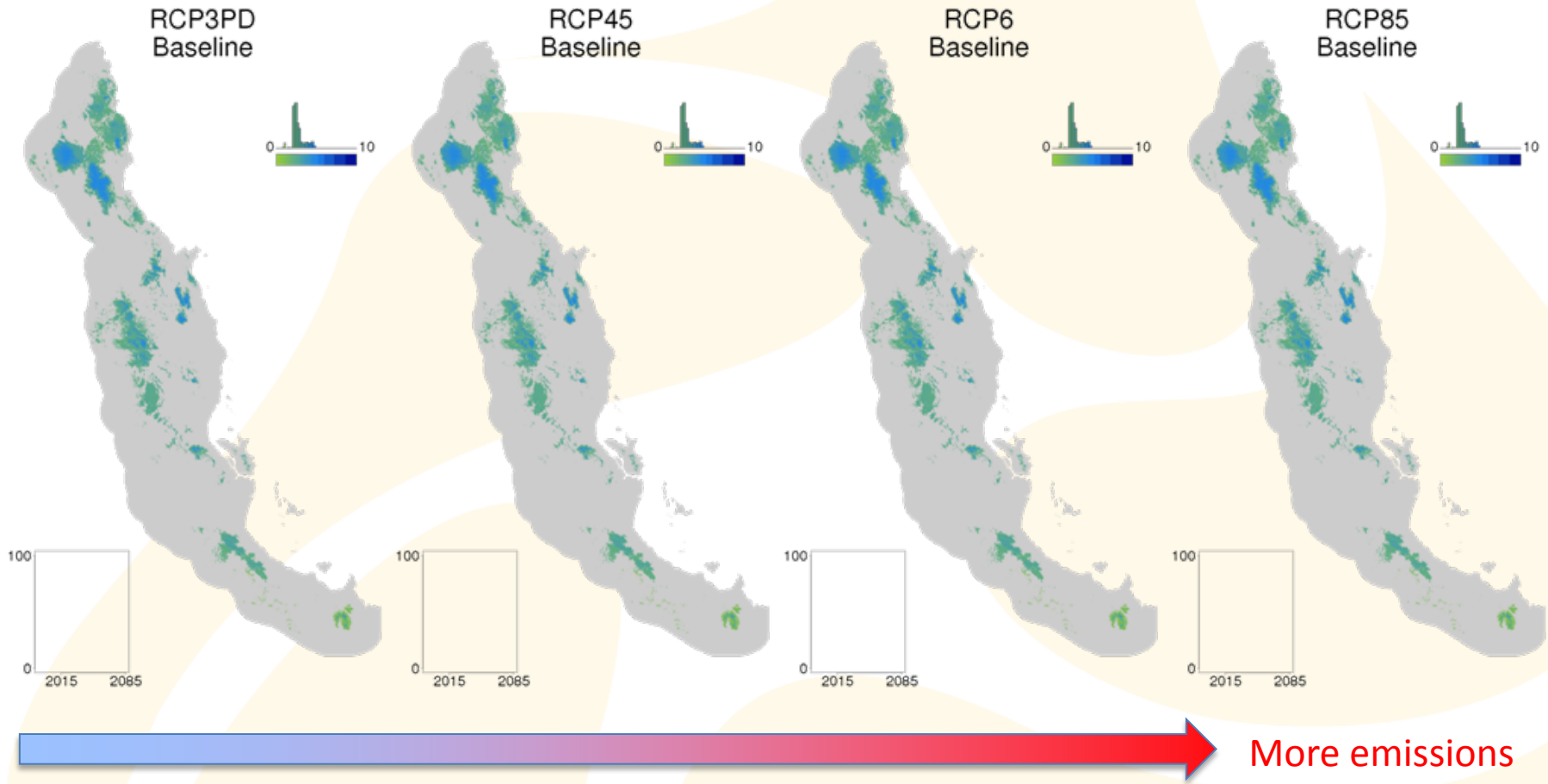
Thermal refugia:

Areas that provide most shelter to the *highest* number of species with the *lowest* mean resilience

Future projections of thermal refugia under different climate change scenarios

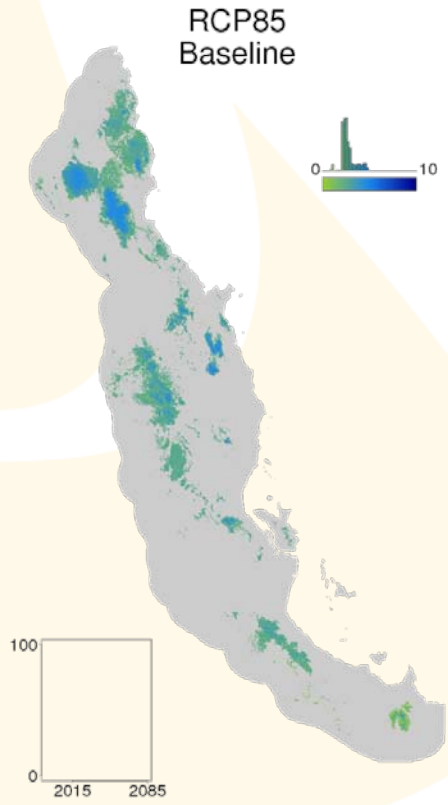


Future projections of thermal refugia under different climate change scenarios



Vulnerability

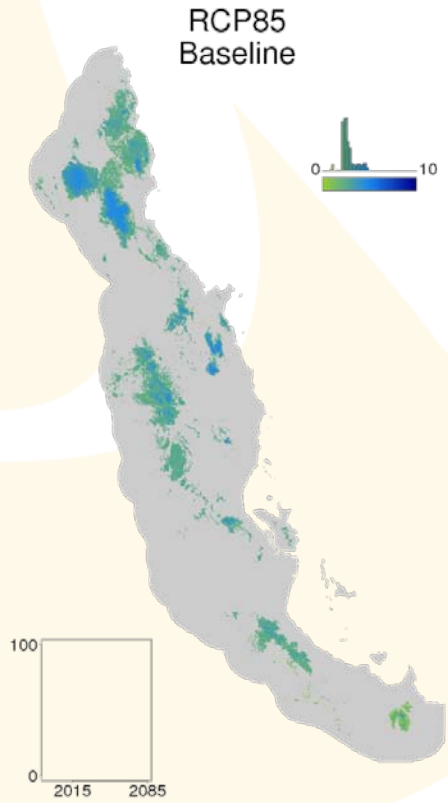
The thermal refugia are also useful for conservation management



Vulnerability

The thermal refugia are also useful for conservation management

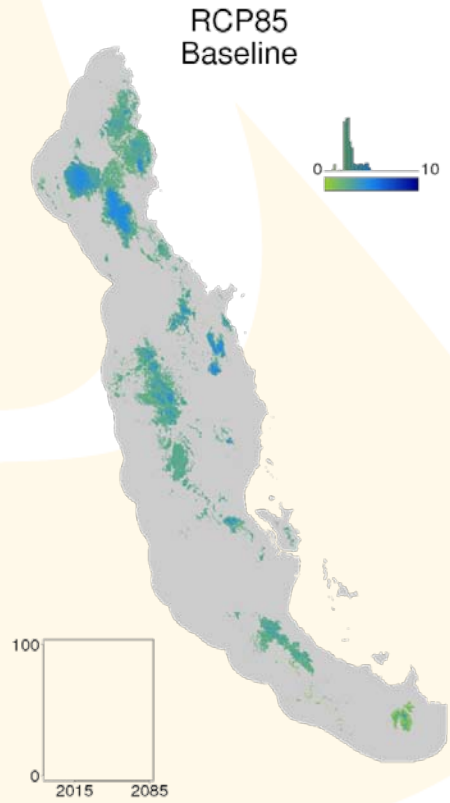
- Areas where species would currently benefit most from habitat protection



Vulnerability

The thermal refugia are also useful for conservation management

- Areas where species would currently benefit most from habitat protection
- Areas that can act as a population source if connected to areas affected by extreme events



Vulnerability

- The previous maps showed the *relative* vulnerability of species assemblages to extreme heat events

Victoria's rifle bird *(Ptiloris victoriae)*

Vulnerability

- The previous maps showed the *relative* vulnerability of species assemblages to extreme heat events

  - useful for efforts that focus on protecting broader segments of the Wet Tropics' biodiversity.

Victoria's rifle bird *(Ptiloris victoriae)*

Vulnerability

- The previous maps showed the *relative* vulnerability of species assemblages to extreme heat events

  - useful for efforts that focus on protecting broader segments of the Wet Tropics' biodiversity.

- We can also produce *absolute* vulnerability maps based on the thermotolerance of species

Victoria's rifle bird *(Ptiloris victoriae)*

Vulnerability

- The previous maps showed the *relative* vulnerability of species assemblages to extreme heat events

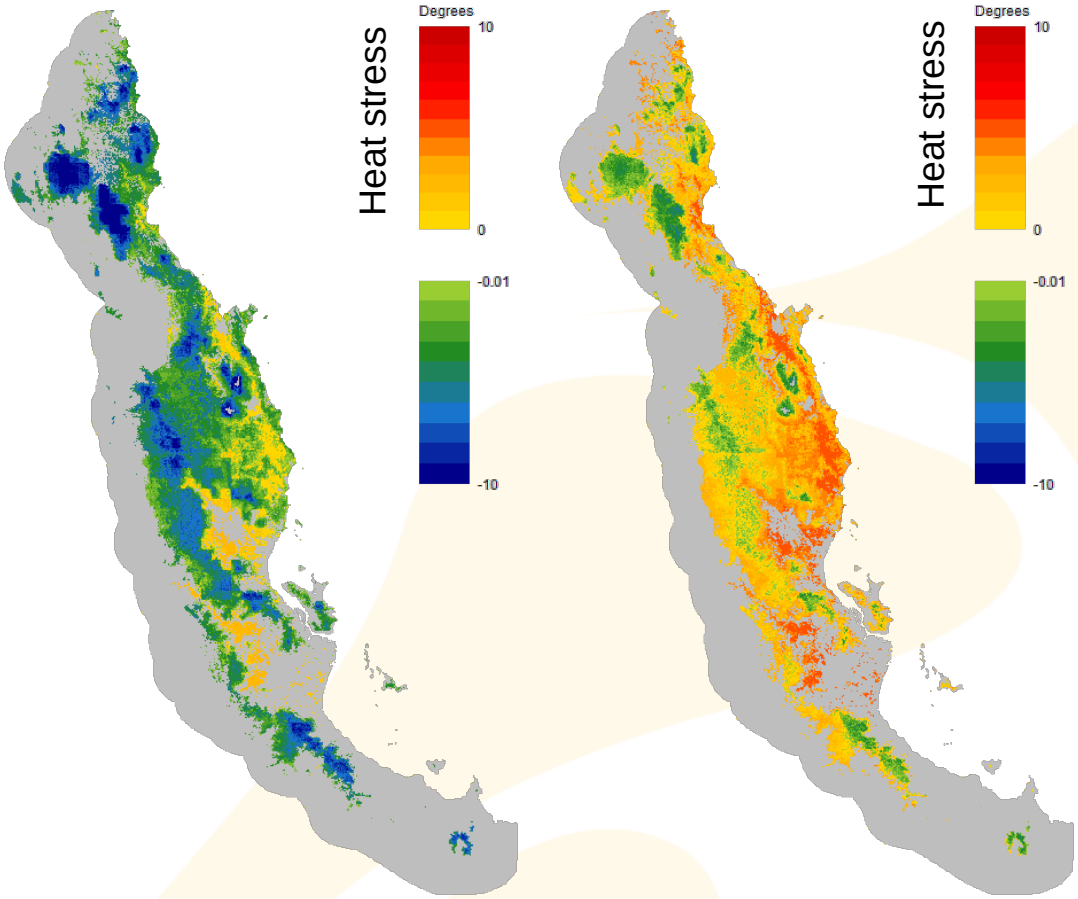
  - useful for efforts that focus on protecting broader segments of the Wet Tropics' biodiversity.

- We can also produce *absolute* vulnerability maps based on the thermotolerance of species

  - useful for efforts that focus on protecting individuals species.

Victoria's rifle bird *(Ptiloris victoriae)*

Current heat stress vulnerability

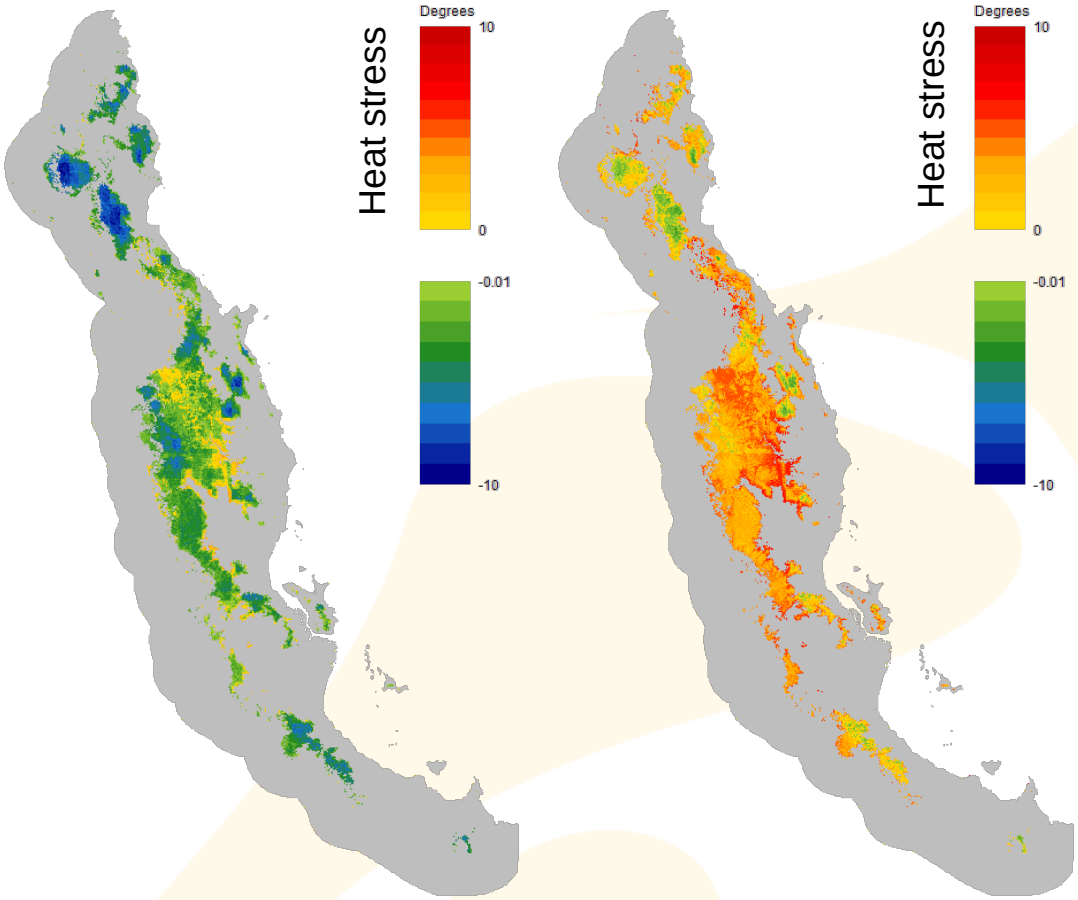


95th percentile hottest day of the year

Hottest day of the year

Victoria's rifle bird *(Ptiloris victoriae)*

Current heat stress vulnerability

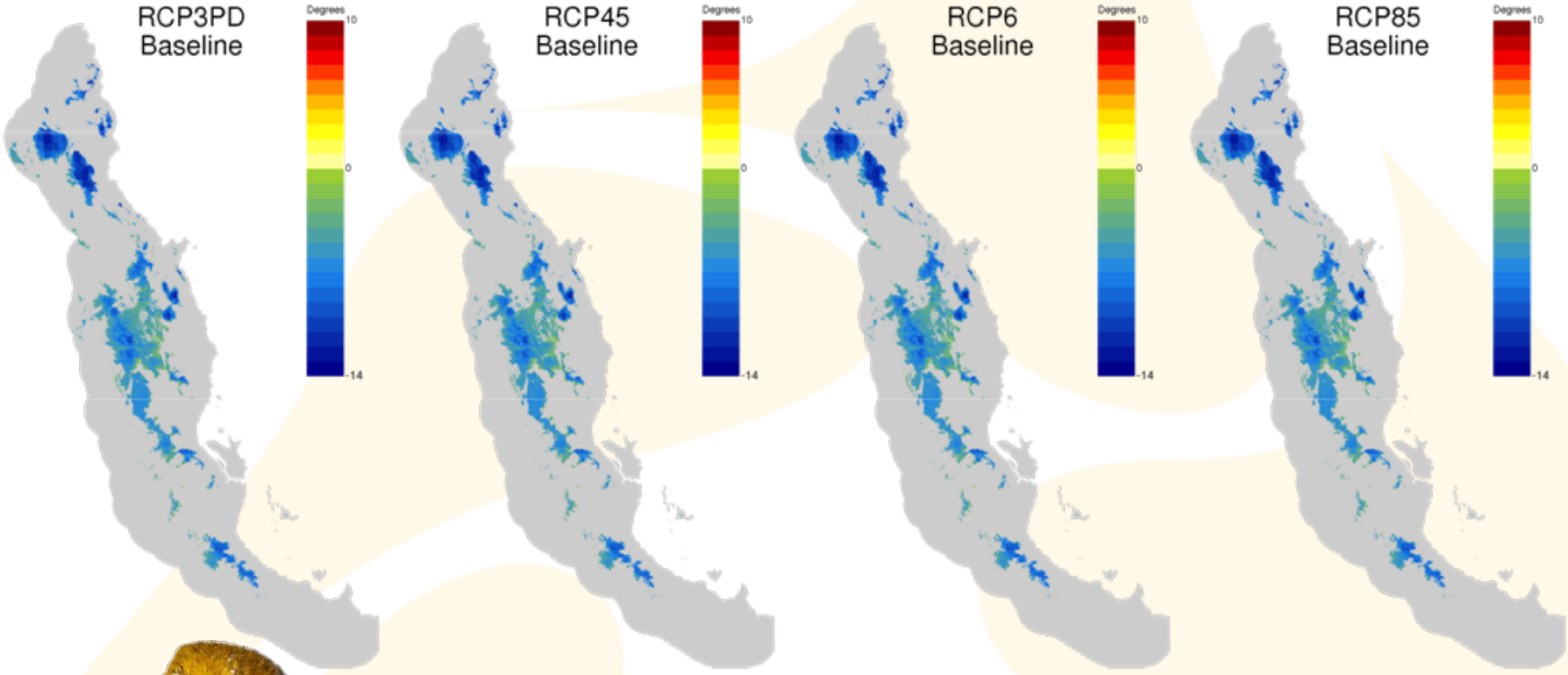


95th percentile hottest day of the year

Hottest day of the year

Bowers shrike-thrush (*Colluricincla boweri)*

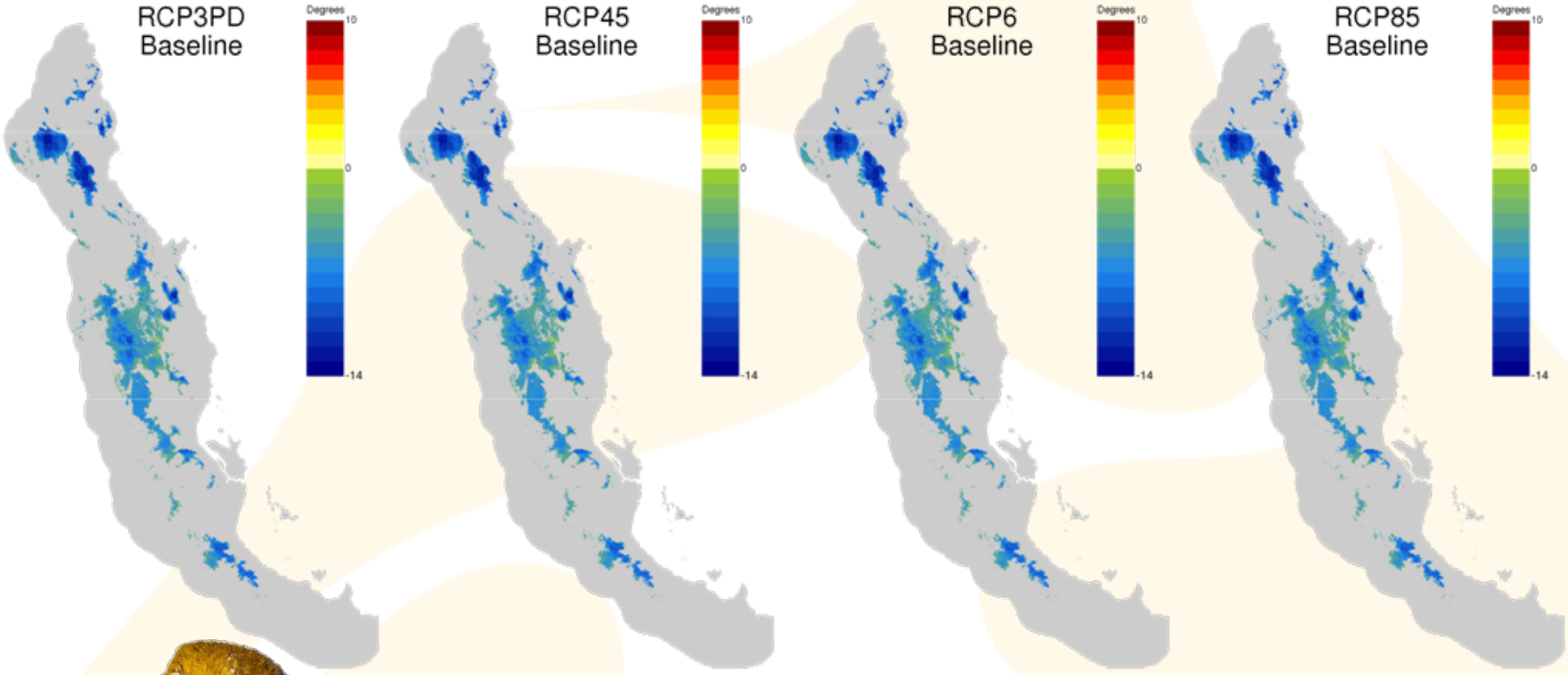
Projections of heat stress vulnerability



More emissions

golden bowerbird (*Prionodura newtoniana*)

Projections of heat stress vulnerability



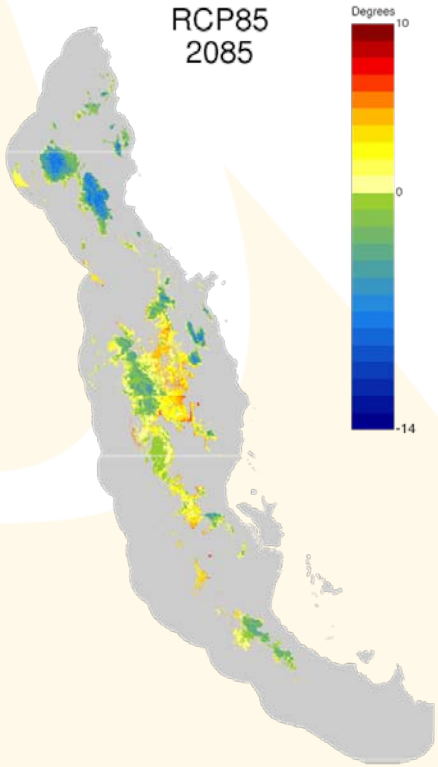
More emissions

golden bowerbird (*Prionodura newtoniana*)

Vulnerability

Absolute future projections of heat stress

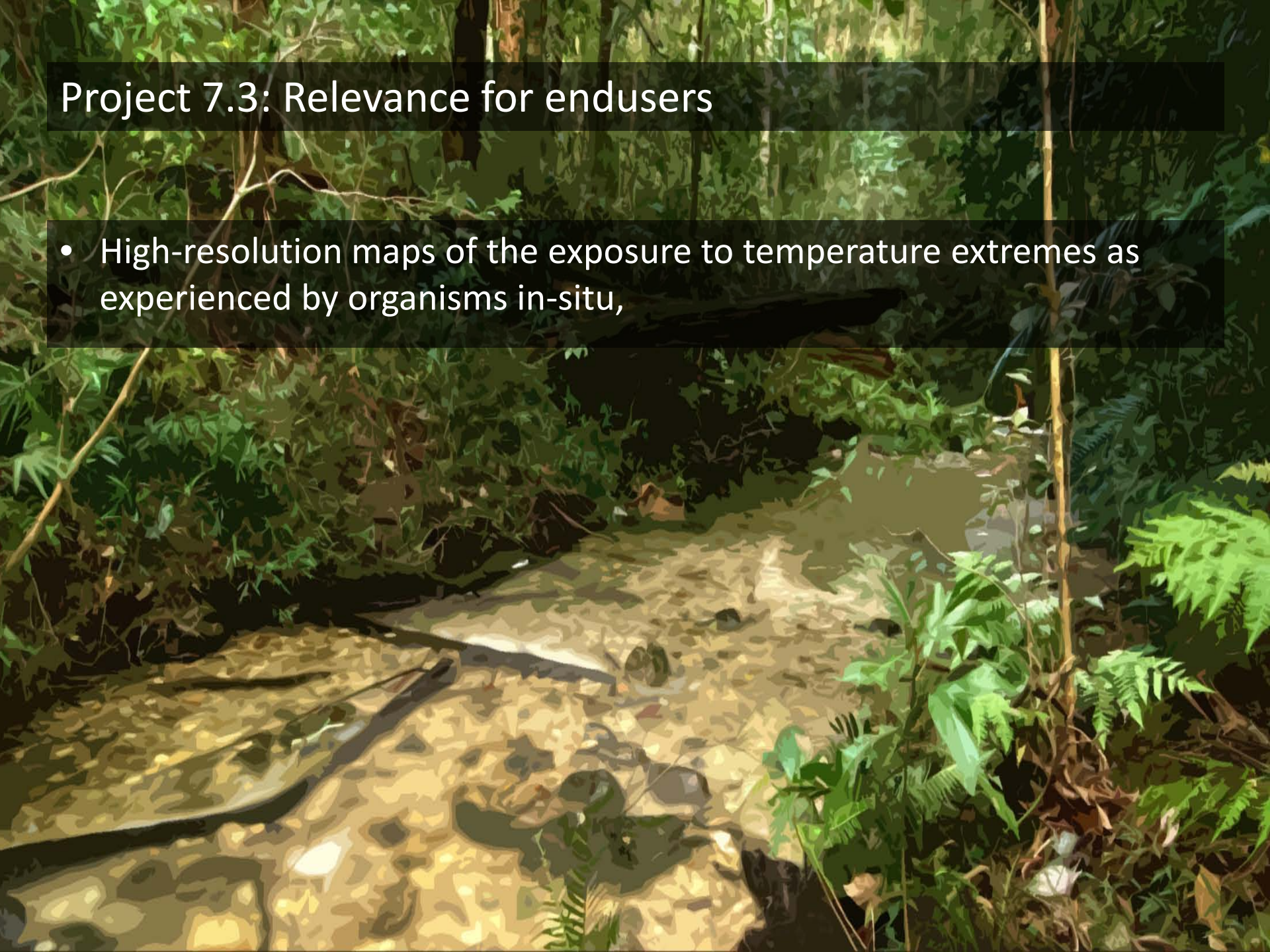
- Models can be fed with physiology-informed hourly or daily temperature regimes
- Useful for efforts that focus on protecting individuals species, in specific areas, and against particular thermal regimes.



Project 7.3: Relevance for endusers

Project 7.3: Relevance for endusers

- High-resolution maps of the exposure to temperature extremes as experienced by organisms in-situ,



Project 7.3: Relevance for endusers

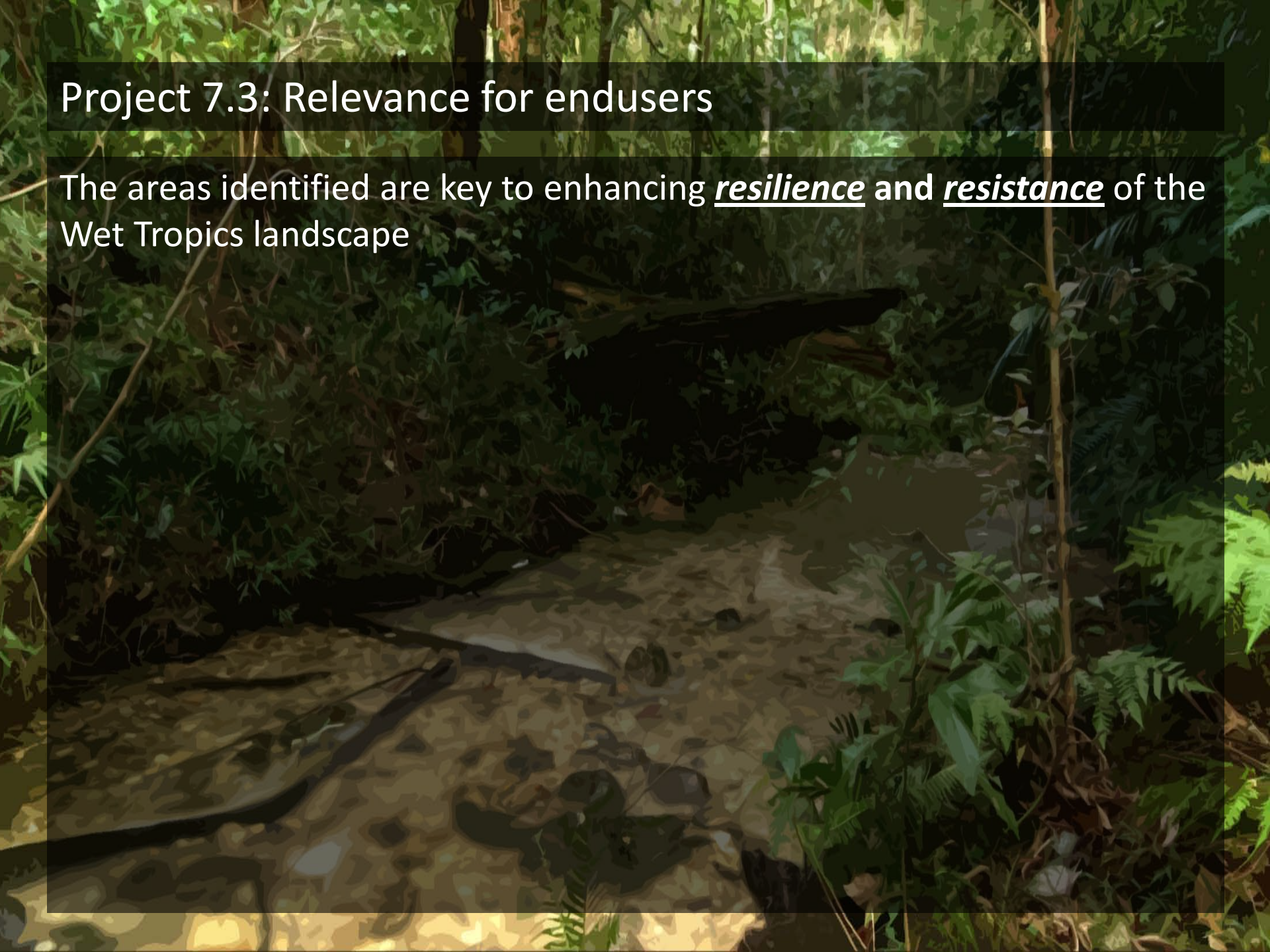
- High-resolution maps of the exposure to temperature extremes as experienced by organisms in-situ,
- Accurate estimates of the sensitivities of rainforest vertebrates to temperature extremes.

Project 7.3: Relevance for endusers

- High-resolution maps of the exposure to temperature extremes as experienced by organisms in-situ,
- Accurate estimates of the sensitivities of rainforest vertebrates to temperature extremes.
- Detailed maps of the areas where vertebrate biodiversity is most and least vulnerable to temperature extremes, both in the present and in the future

Project 7.3: Relevance for endusers

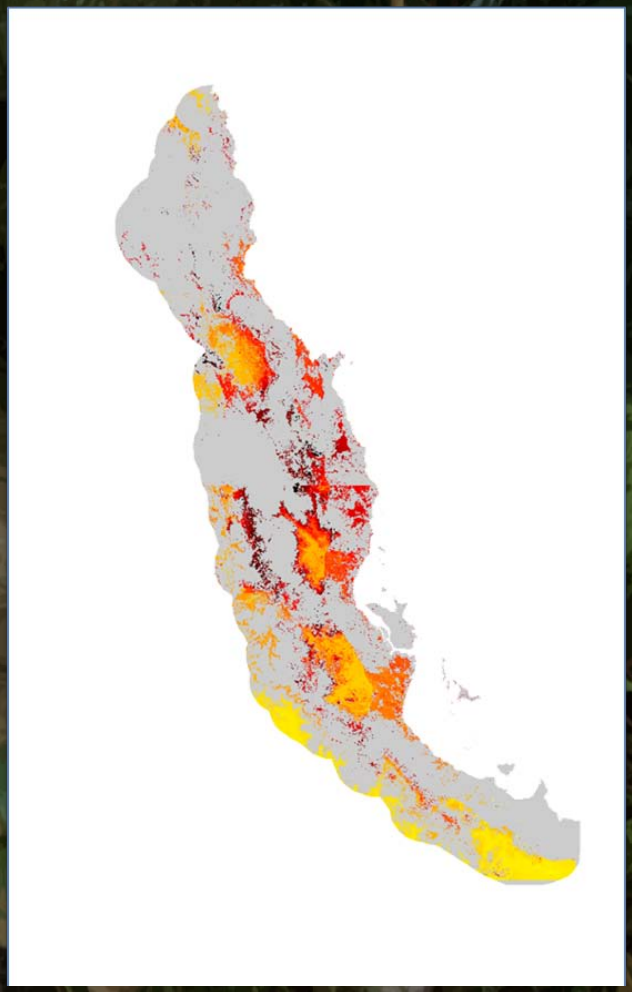
The areas identified are key to enhancing ***resilience*** **and** ***resistance*** of the Wet Tropics landscape



Project 7.3: Relevance for endusers

The areas identified are key to enhancing ***resilience*** **and** ***resistance*** of the Wet Tropics landscape

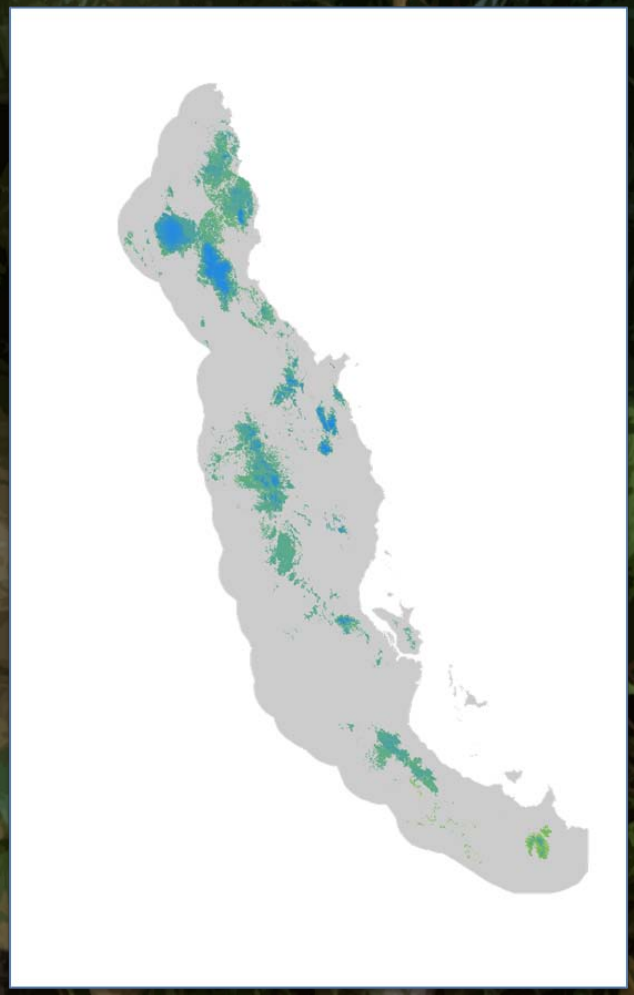
- Thermal hotspots should be foci for habitat restoration & enhancement



Project 7.3: Relevance for endusers

The areas identified are key to enhancing ***resilience*** **and** ***resistance*** of the Wet Tropics landscape

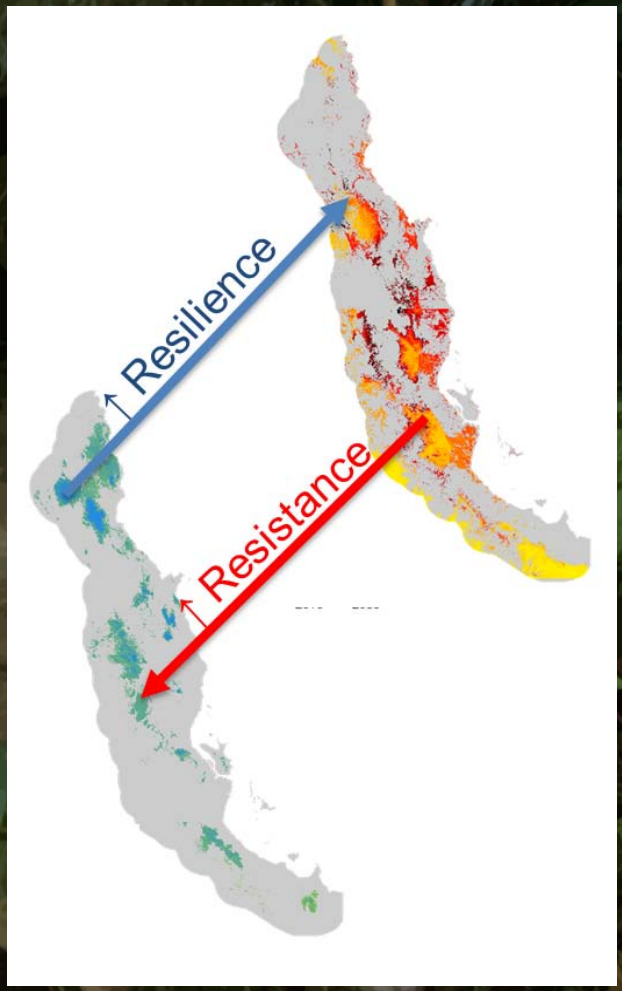
- Thermal hotspots should be foci for habitat restoration & enhancement
- Thermal refugia should be foci for habitat protection



Project 7.3: Relevance for endusers

The areas identified are key to enhancing ***resilience*** **and** ***resistance*** of the Wet Tropics landscape

- Thermal hotspots should be foci for habitat restoration & enhancement
- Thermal refugia should be foci for habitat protection



➢ Combined with promoting the connectivity between thermal hotspots and refugia, this will improve the resilience and resistance of wildlife populations to increasingly extreme temperature events

THANK YOU

National Environmental Research Program

CONTACT

Name: Justin Welbergen

Organisation: James Cook University, Townsville

Phone: (07) 4781 4479

Email: Justin.Welbergen@jcu.edu.au

CENTRE FOR Tropical Biodiversity & Climate Change

JAMES COOK UNIVERSITY AUSTRALIA