Sir Arnold Theiler Memorial Lecture
Faculty of Veterinary Science
University of Pretoria

# Large mammals facing climate change


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Leith Meyer, Ned Snelling,
Maartin Strauss, Andrea Fuller

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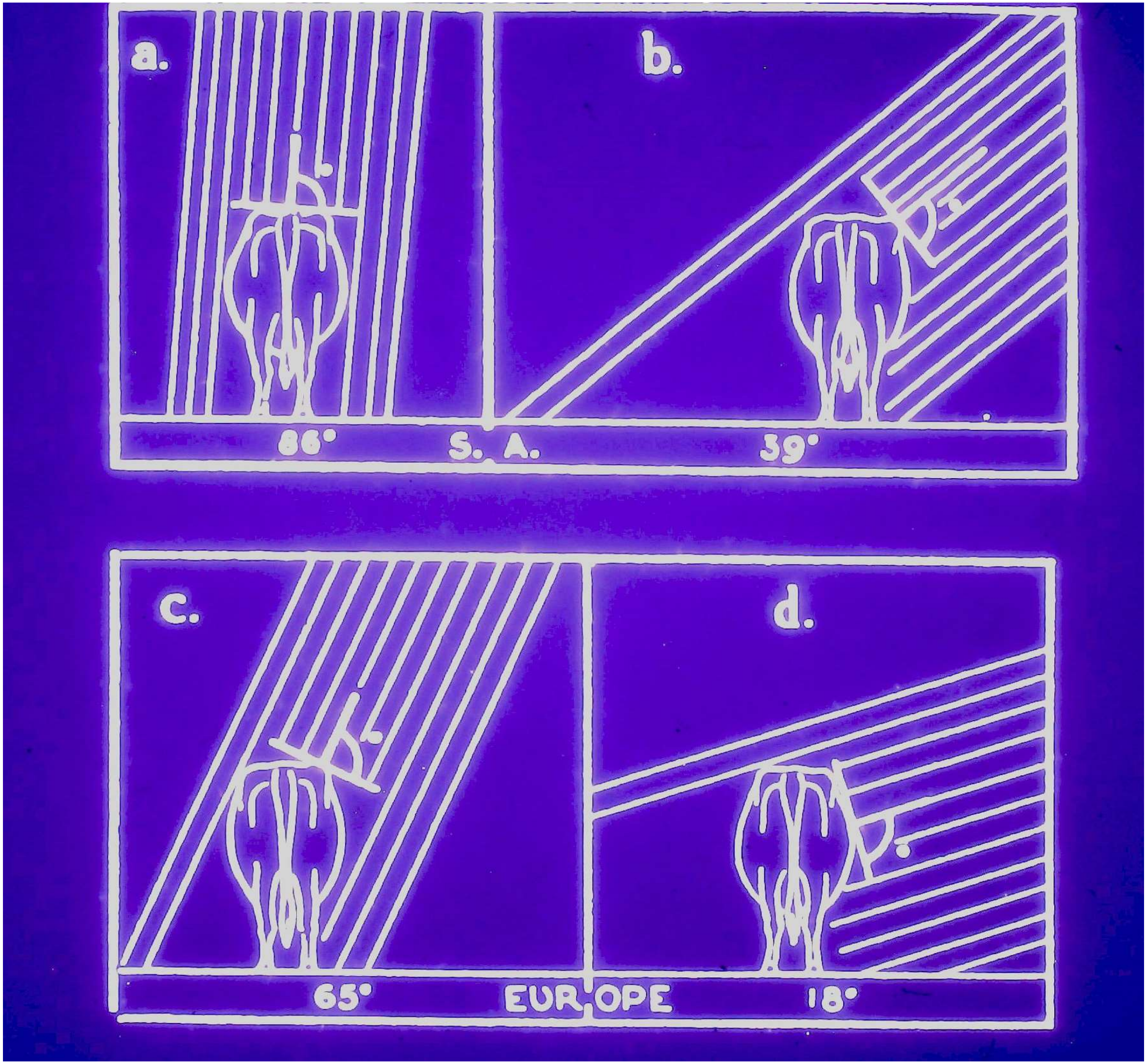
university of south africa UNISA
THE UNIVERSITY OF WESTERN AUSTRALIA



a.
b.
86°
S. A.
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65°
EUROPE
18°

# Gertrud Riemerschmid

Riemerschmid G (1943) Some aspects of **solar radiation** in its relation to **cattle** in South Africa and Europe. *Onderstepoort J Vet Sci Anim Ind* 18:327-353.

Riemerschmid G (1943) The amount of **solar radiation** and its absorption on the hairy coat of **cattle** under South African and European conditions. *J S Afr Vet Assoc* 14:121-141

Riemerschmid G, Elder JS (1945) The absorptivity for **solar radiation** of different coloured hairy coats of **cattle**. *Onderstepoort J Vet Sci Anim Ind* 20:223 -234

# $CO_2$ emission (g per year per $GDP)

| | **2010** |
|---|---|
| South Africa | 1230 |
| Zimbabwe | 960 |
| Namibia | 290 |
| | |
| USA | 360 |
| Australia | 320 |
| New Zealand | 220 |
| UK | 200 |

Calculated from World Bank data

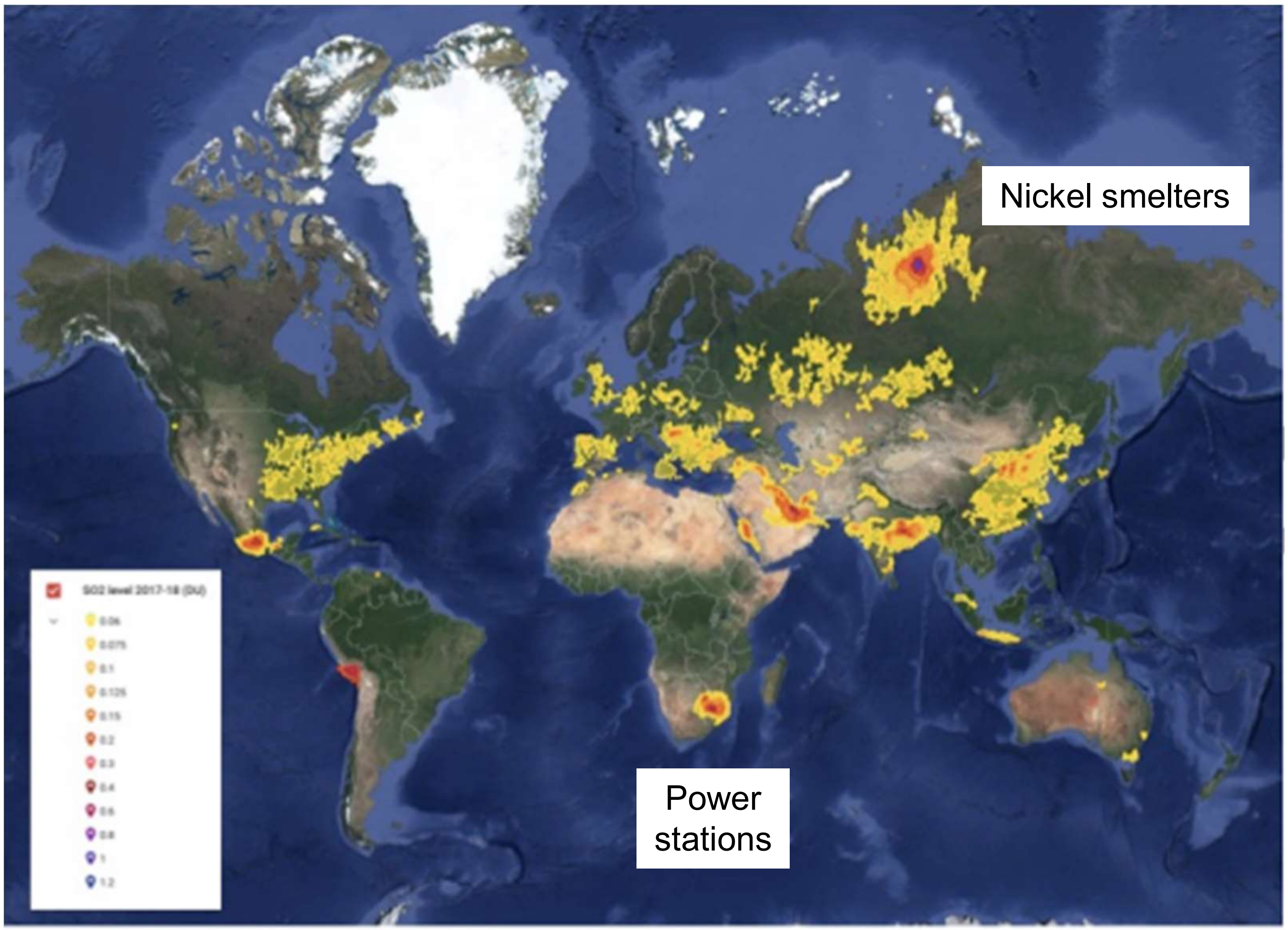
# Government coal subsidies: G20 countries

| Rank order | GDP (US$) |
|---|---|
| China | $13.4 \times 10^{12}$ |
| India | $2.7 \text{ X } 10^{12}$ |
| Japan | $4.8 \text{ X } 10^{12}$ |
| South Africa | $0.4 \text{ X } 10^{12}$ |

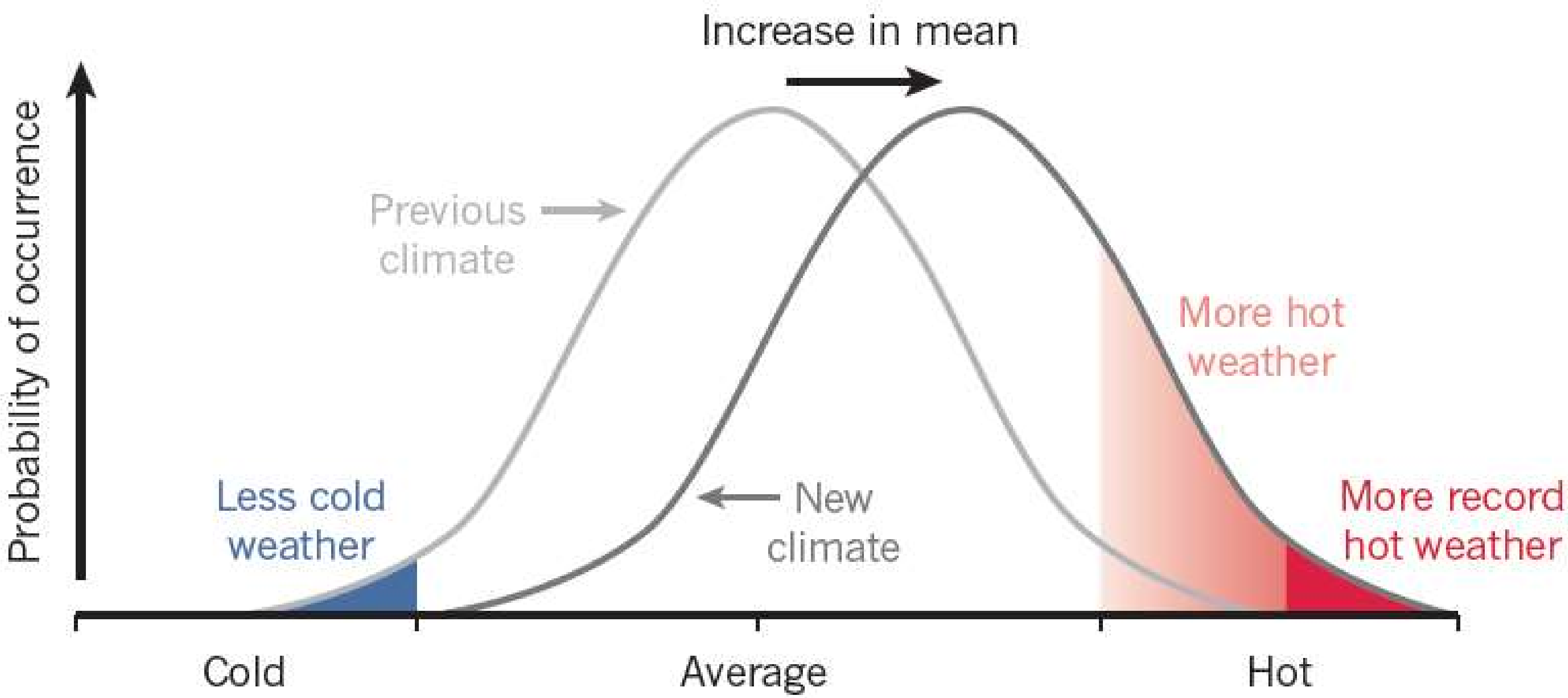
2018 data

Daily Maverick 1 July 2019 and International Monetary Fund

# Hotspots for $SO_2$ emissions

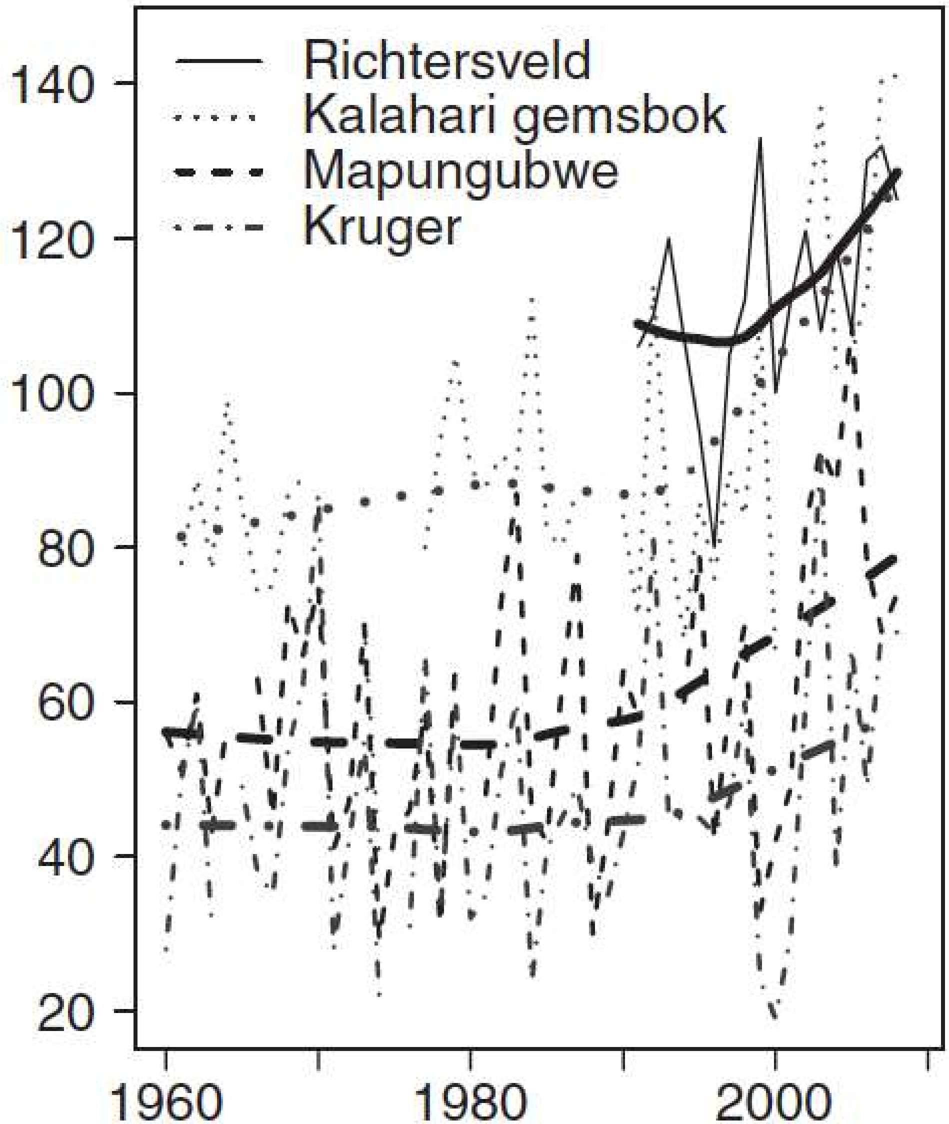



NASA/Greenpeace 2019




Schiermeier *Nature News*, 2011

# Days per year reaching 35°C




Van Wilgen et al. *International Journal of Climatology*, 2015

Bramble Cay mosaic-tailed rat (*Melomys rubicola*)

first mammal species wiped out by human-induced climate change

# Plant toxins get more toxic as temperature increases

Creosote bush resin
*(Larrea tridentata)*

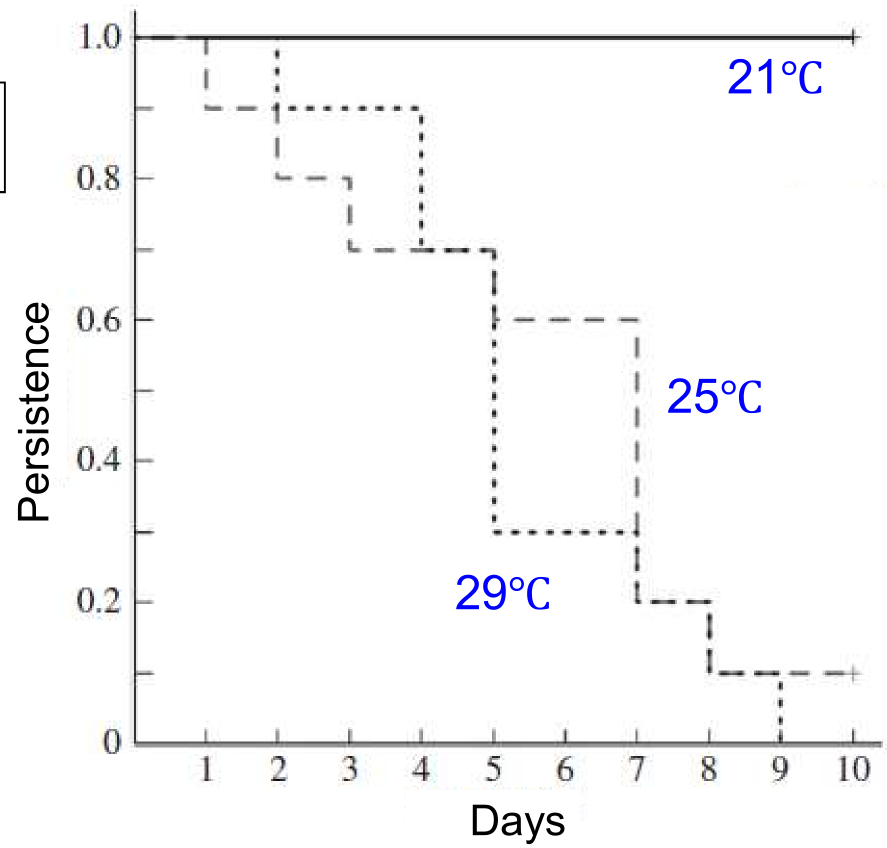
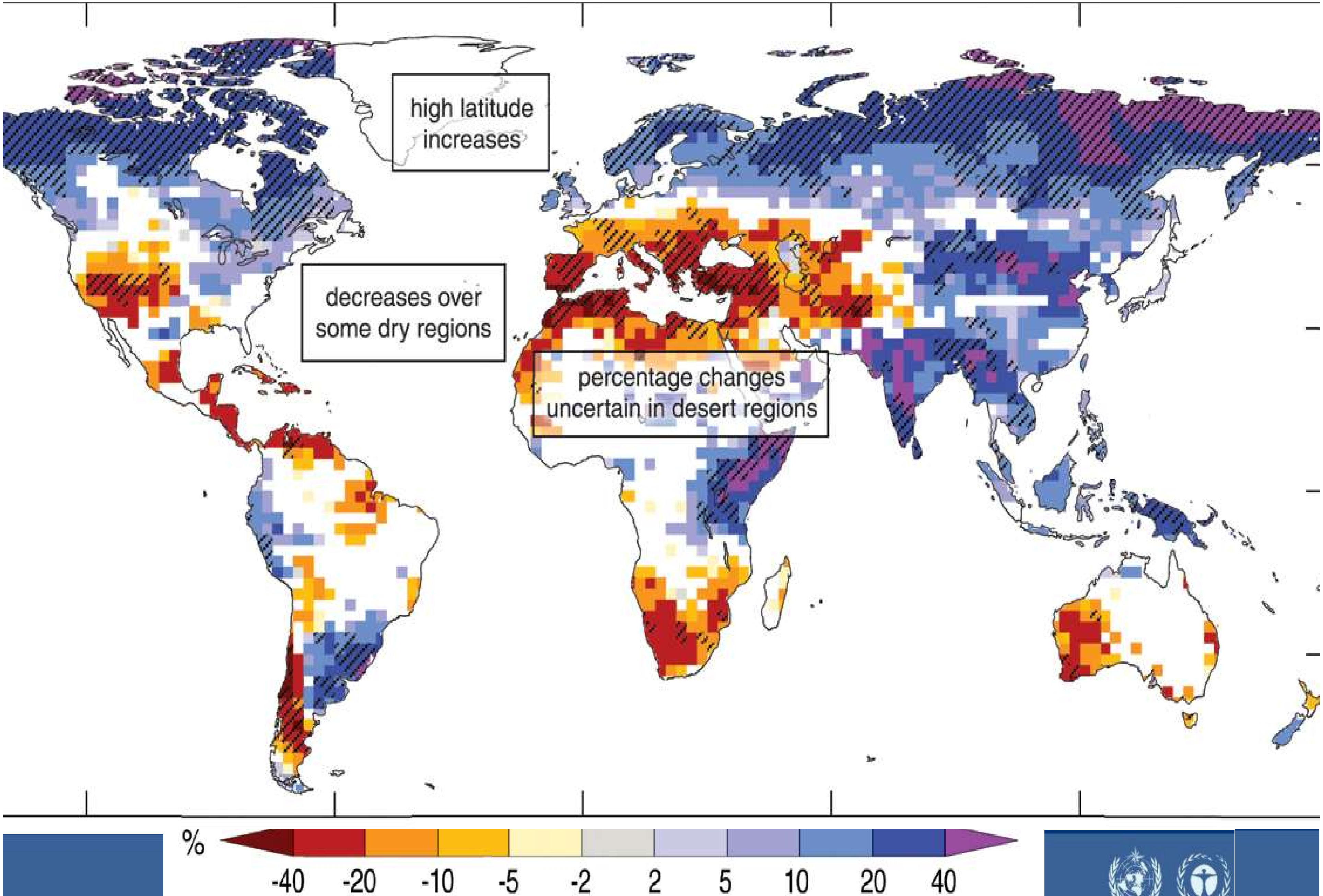



**Figure 4.** Proportion of woodrats remaining in the trial (persistence) while ingesting a controlled dose of creosote (0.36 g resin per day) at three temperatures (cool, solid line; room, grey dashed line; warm, dotted line).

Kurnath et al. *Proceedings of the Royal Society B,* 2016

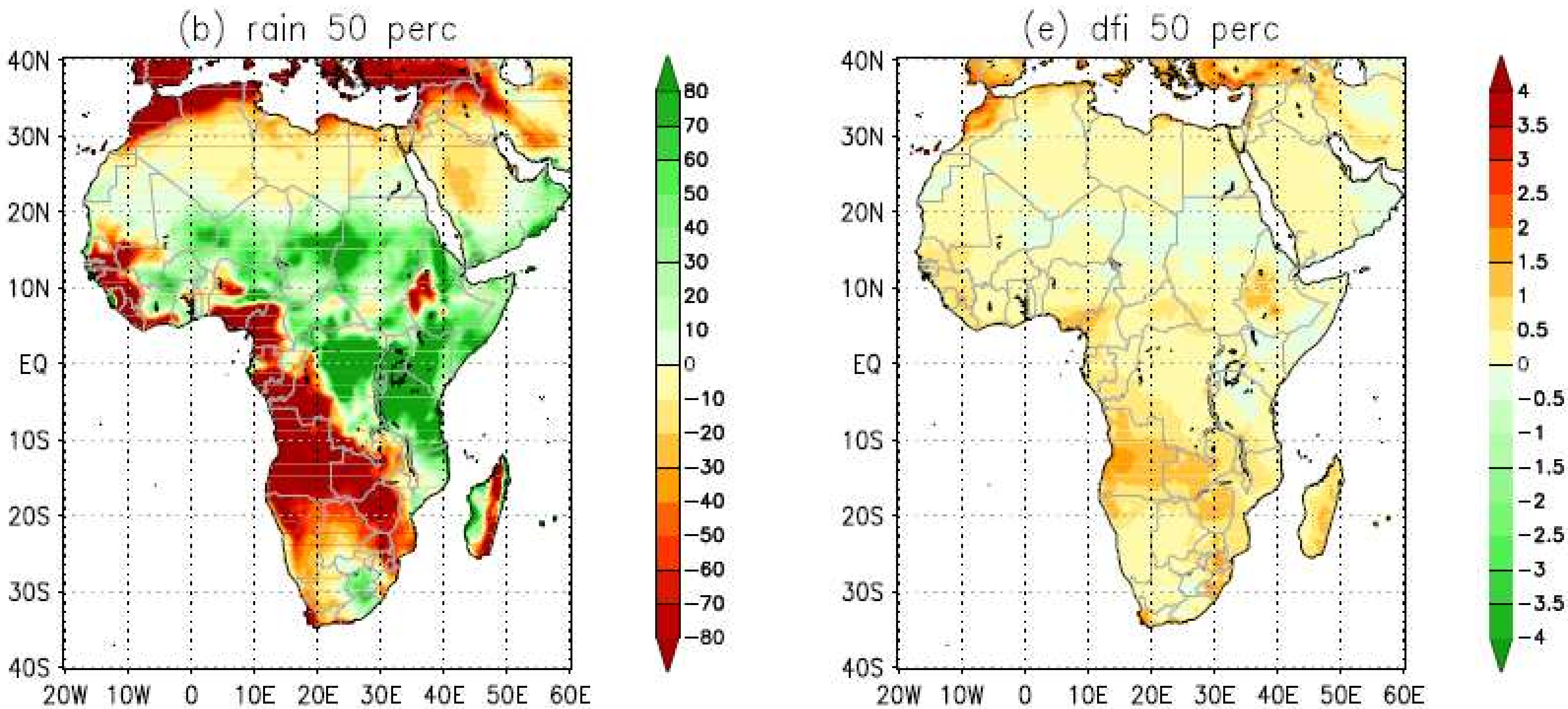



IPCC

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

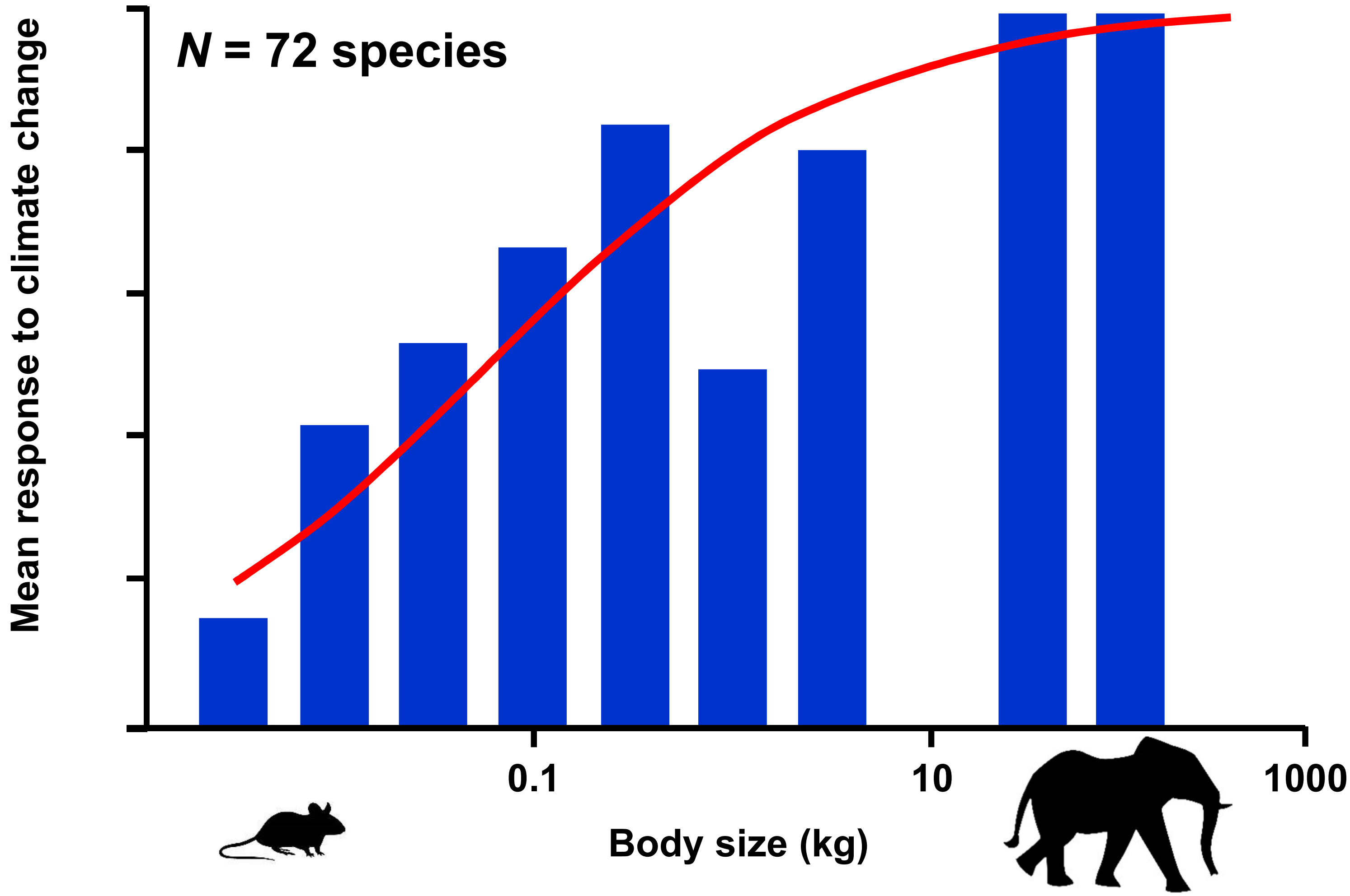
WMO UNEP

# Change in average annual rainfall (mm) and in Keetch-Byram drought index : 2071-2100 vs 1961-1990

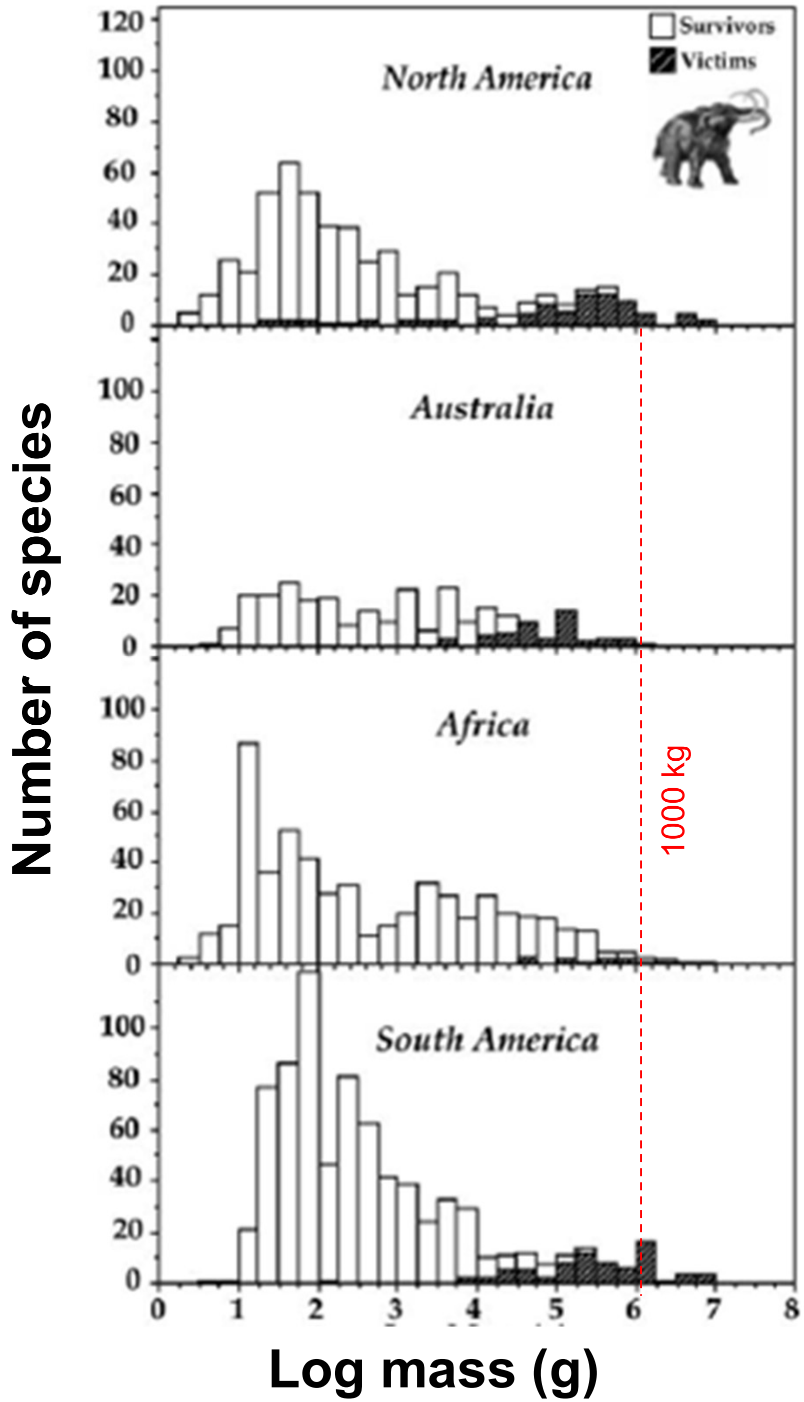



Engelbrecht et al. *Environmental Research Letters*, 2015

# Larger mammals are more vulnerable to global warming




McCain and King *Global Change Biology*, 2014

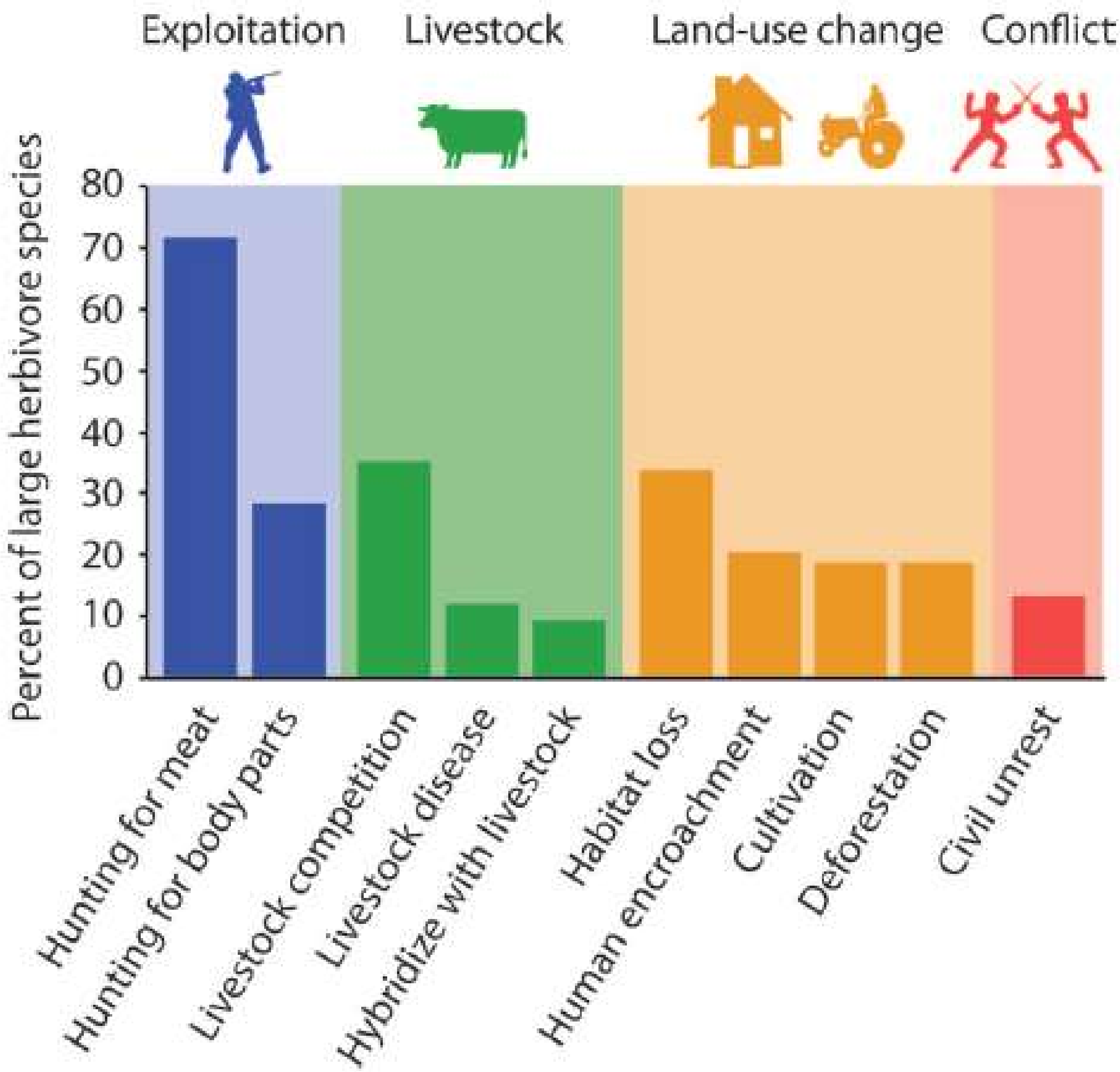



# Late Pleistocene extinction of large mammals

Late Pleistocene
126 000 to 11 700 years ago

Lyons et al. *Evolutionary Ecology Research,* 2004

# Hunting is the biggest threat to large herbivores




Ripple et al. *Science Advances*, 2015

About one-quarter of all mammals are
in danger of extinction, and more than
half of all mammal populations are in decline

Davidson et al. *PNAS,* 2009

The status of large-bodied species, particularly those
above 100 kg (including many iconic taxa), deteriorated
significantly more than small-bodied species (below 10 kg)

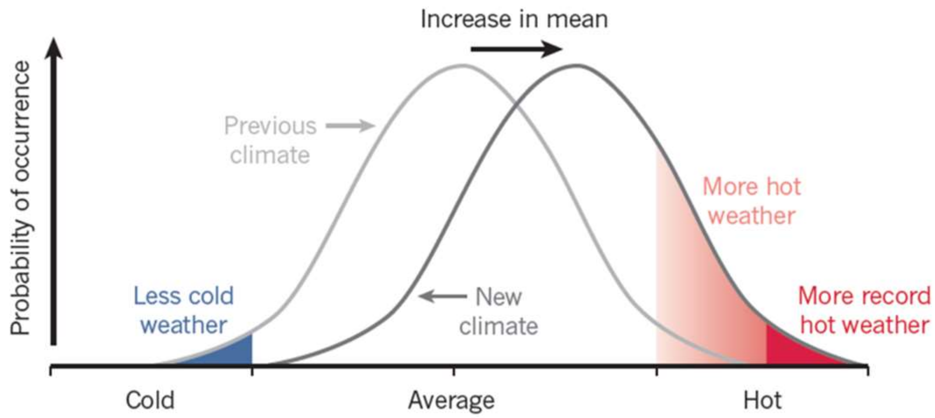
Di Marco et al. *Conservation Biology,* 2014

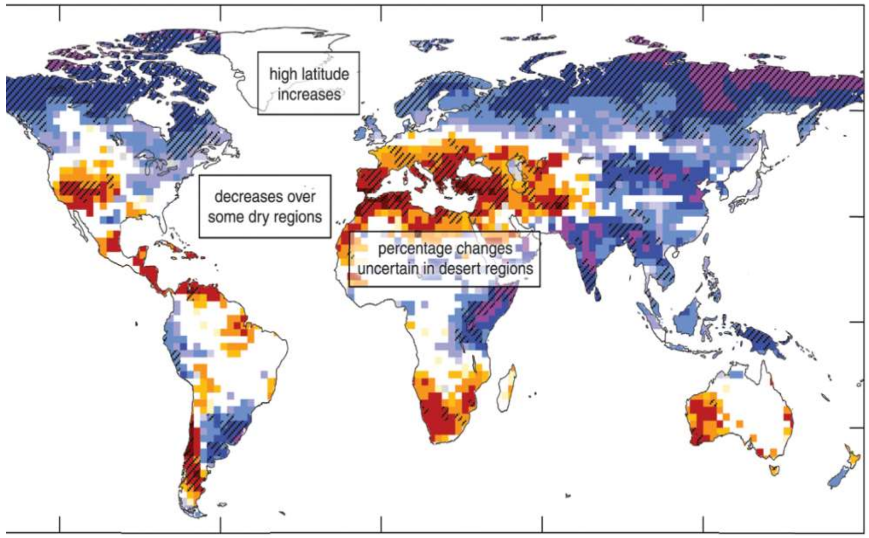
Under mid-range climate change scenarios for 2050, South Africa may lose 69% of its mammals if dispersal is limited

Thomas et al. *Nature*, 2004

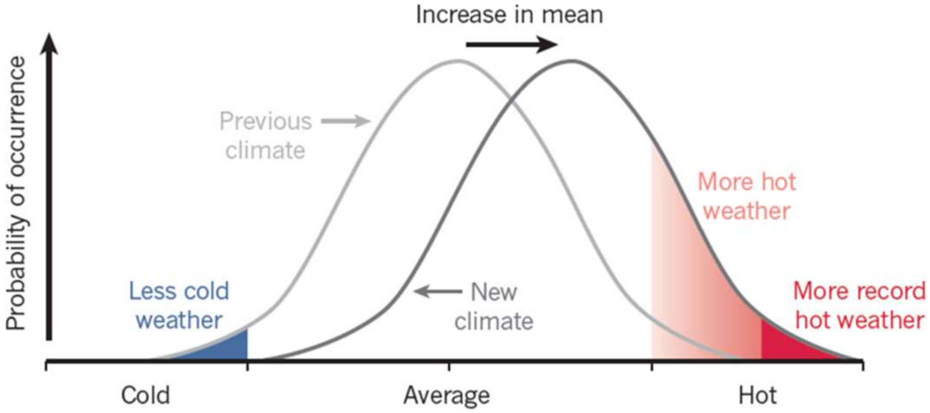
25-40% of a representative sample of 277 African mammalian species is likely to be critically endangered or extinct by 2080

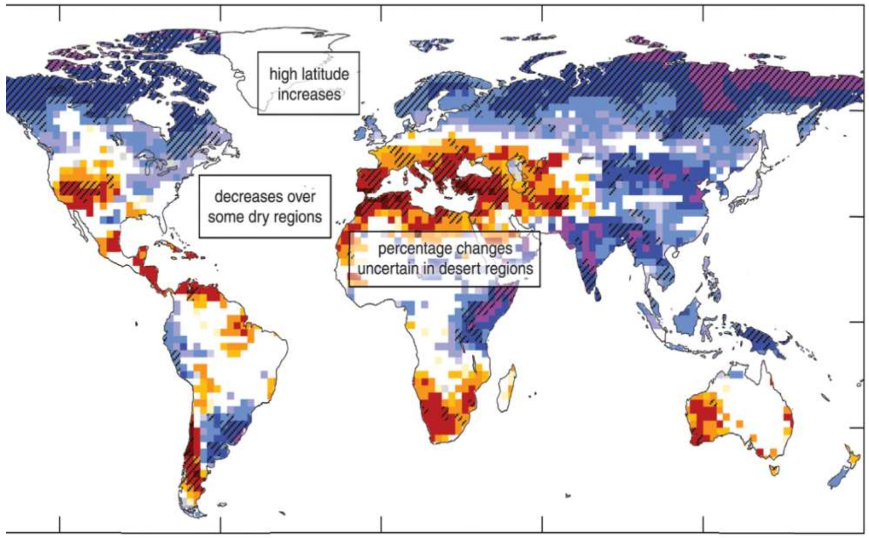
Thuiller et al. *Global Change Biology*, 2006




1. Die out
2. Move
3. Stay put

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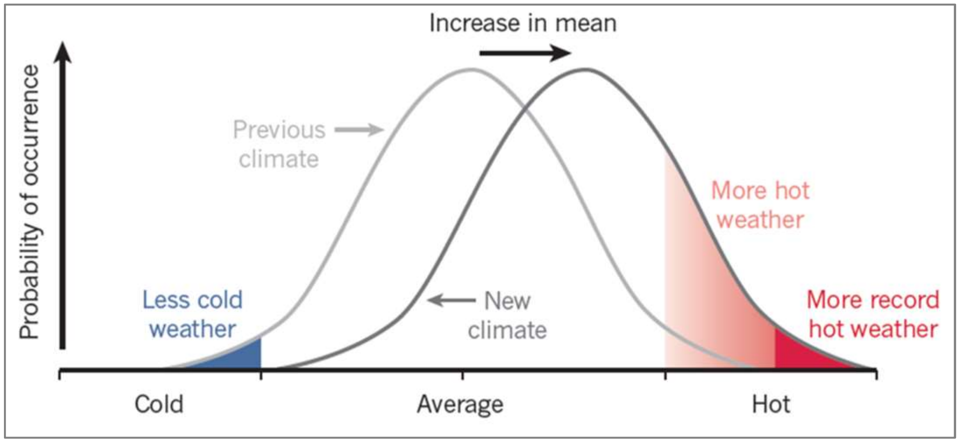
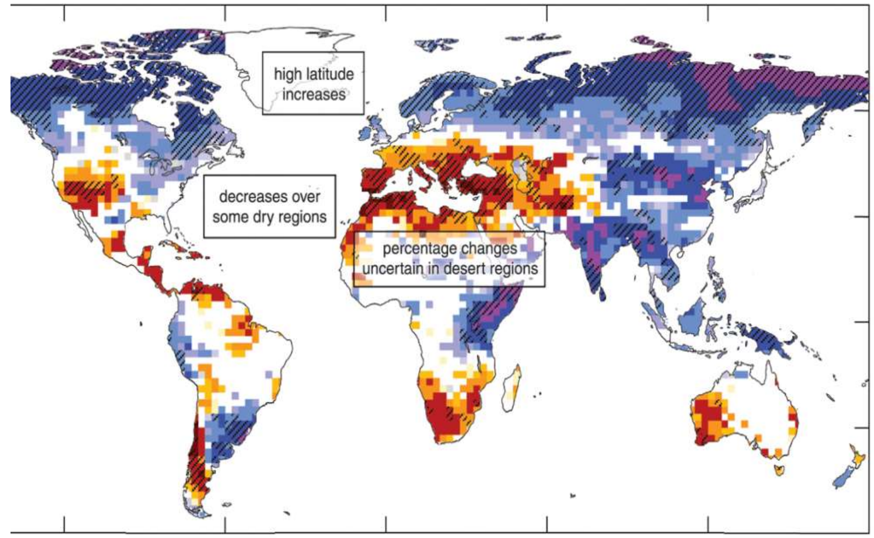
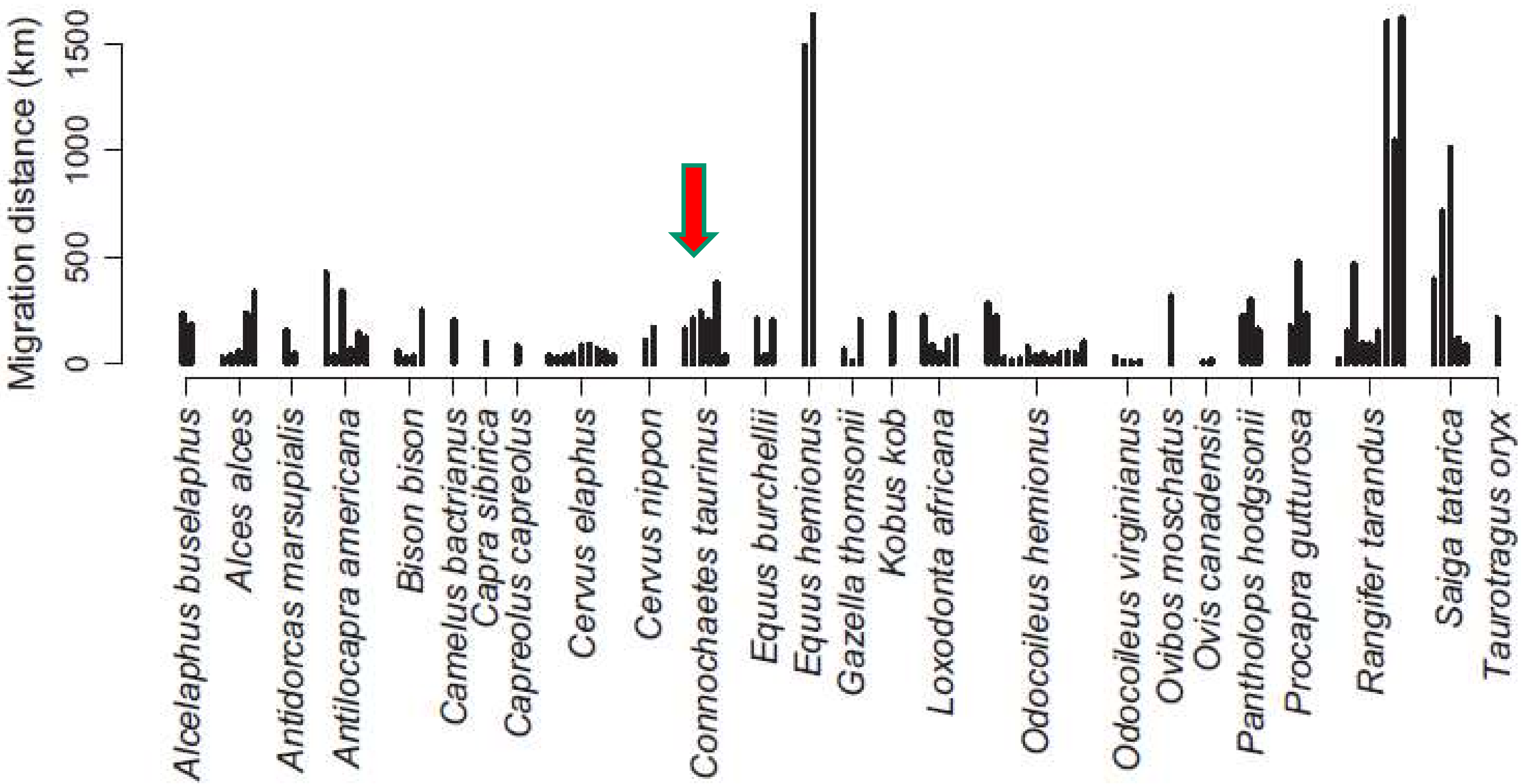



1. Die out
2. Move
3. Stay put

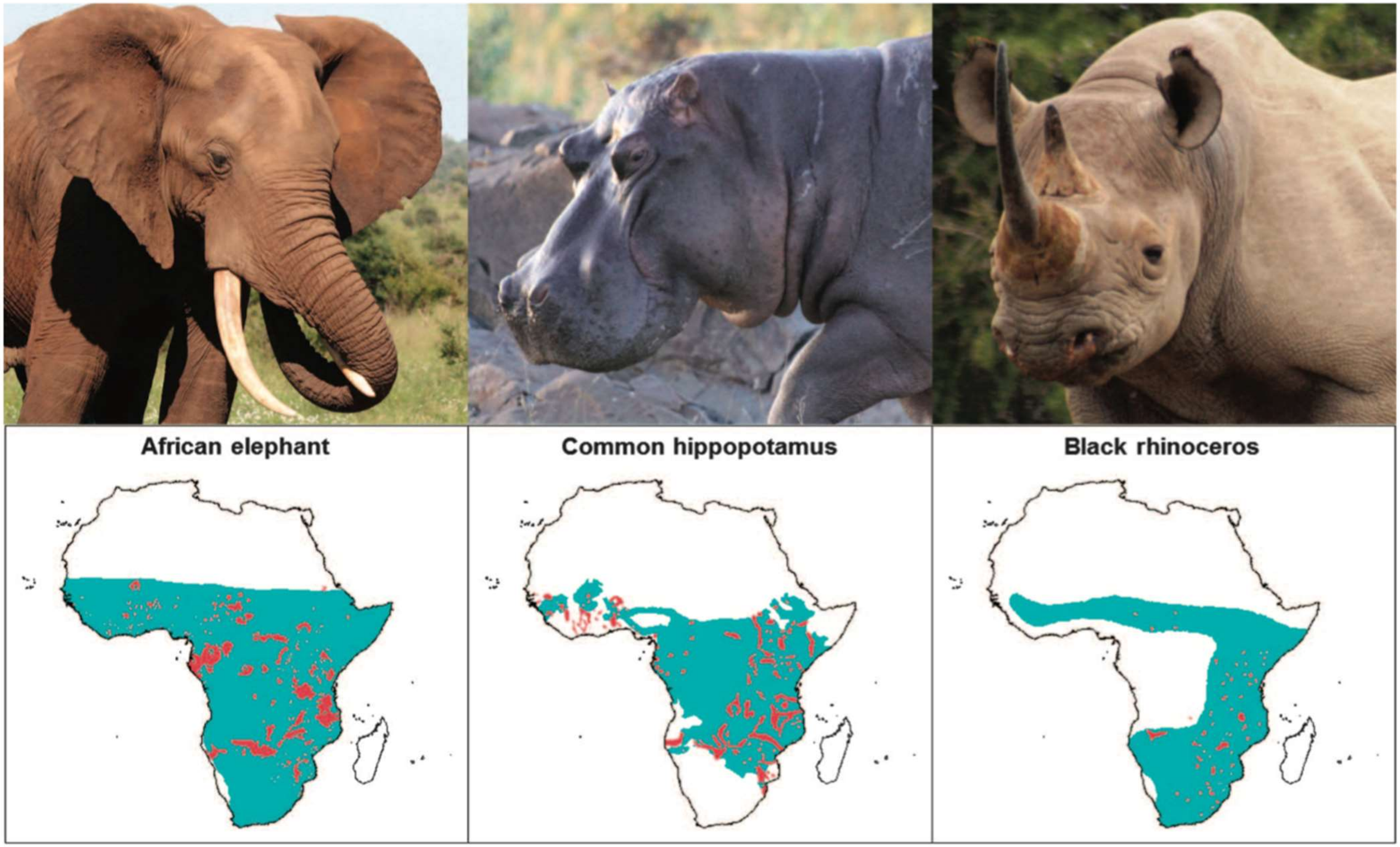
Mara Conservancy

# Migrations of large terrestrial herbivores



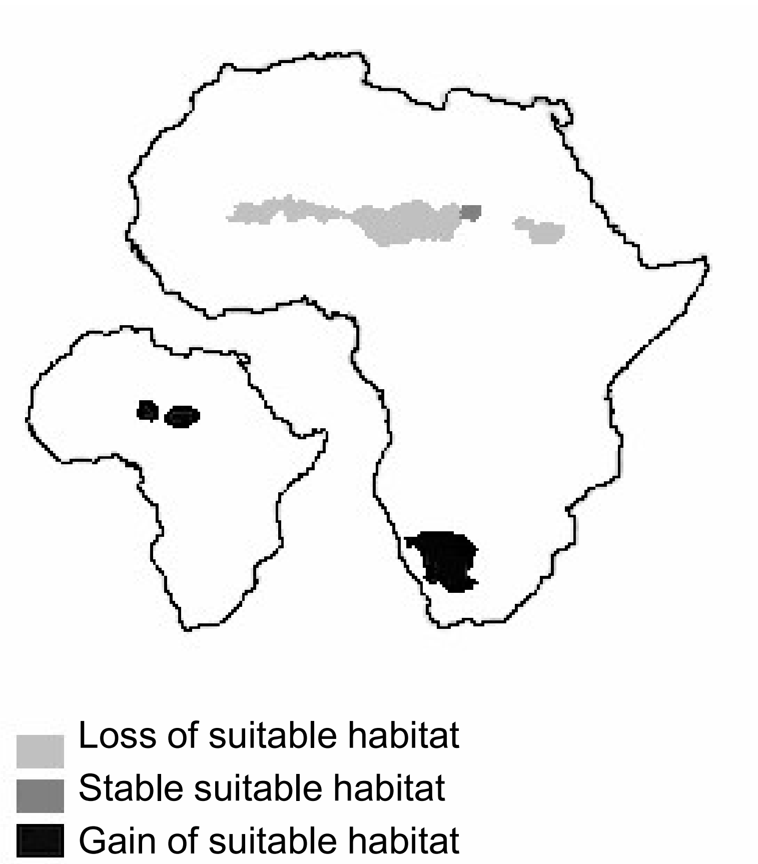

Teitelbaum et al. *Ecology Letters,* 2015

# Anthropogenic land fragmentation prevents movement




Ripple et al. *Science Advances*, 2015

# Emigrate to a suitable environment?



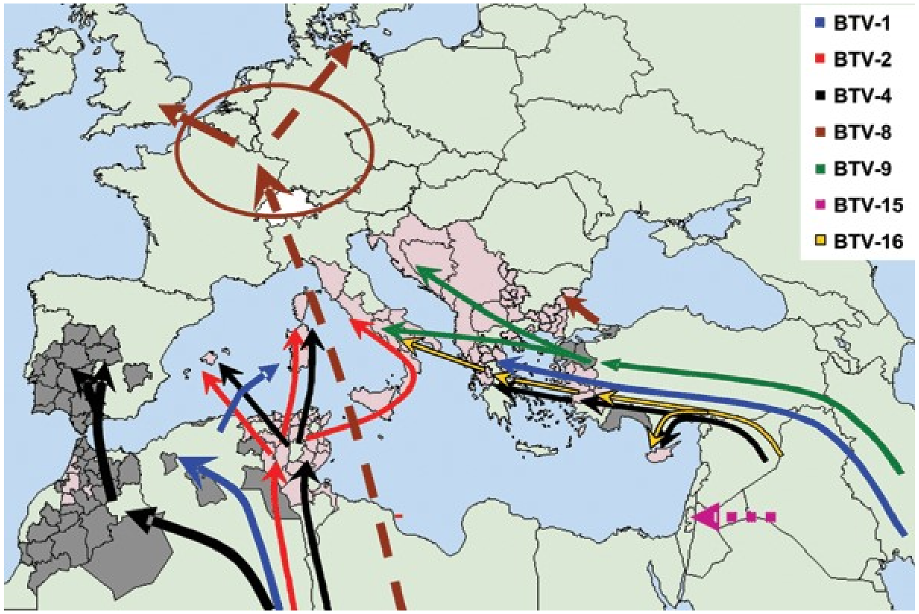

Scimitar-horned oryx


Thuiller et al. *Global Change Biology*, 2006

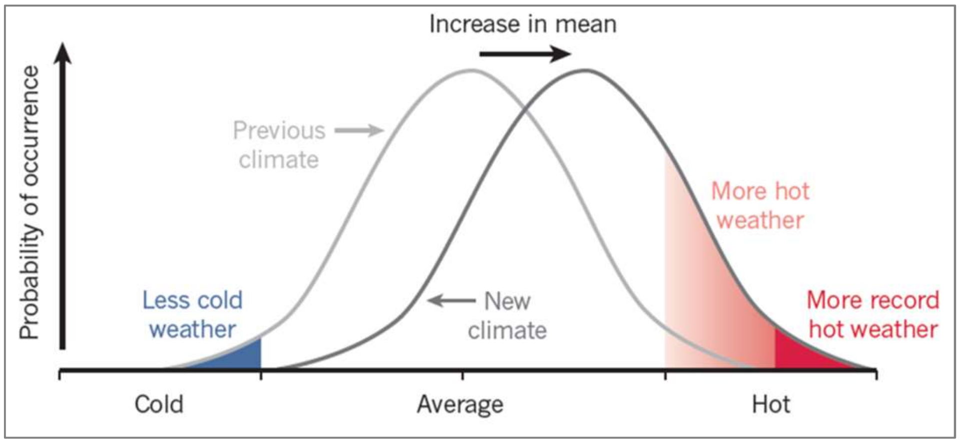
# Host switching

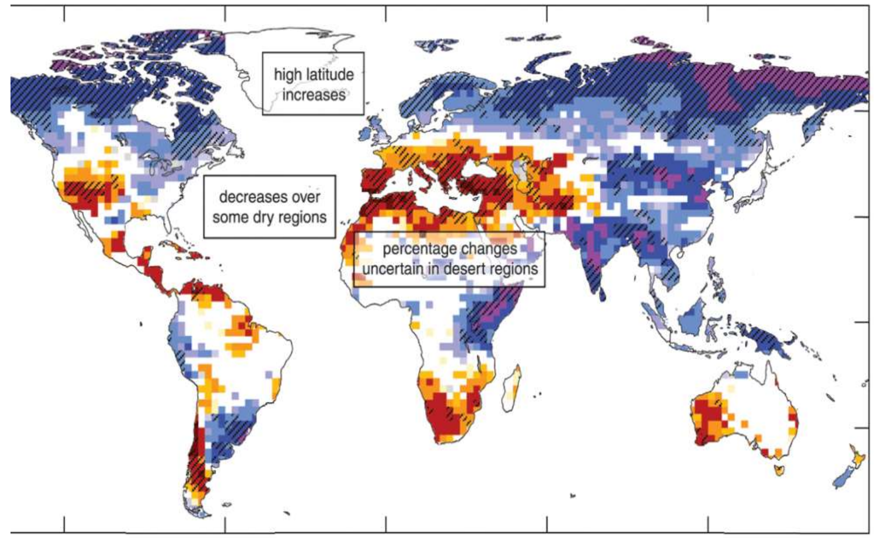
"Parasites are resource specialists with restricted host ranges, yet shifts onto relatively unrelated hosts are common"

Hoberg and Brooks *Philosophical Transactions of the Royal Society*, 2015




Saegerman et al. http://www.cdc.gov/EID/content/14/4/539-G1.htm



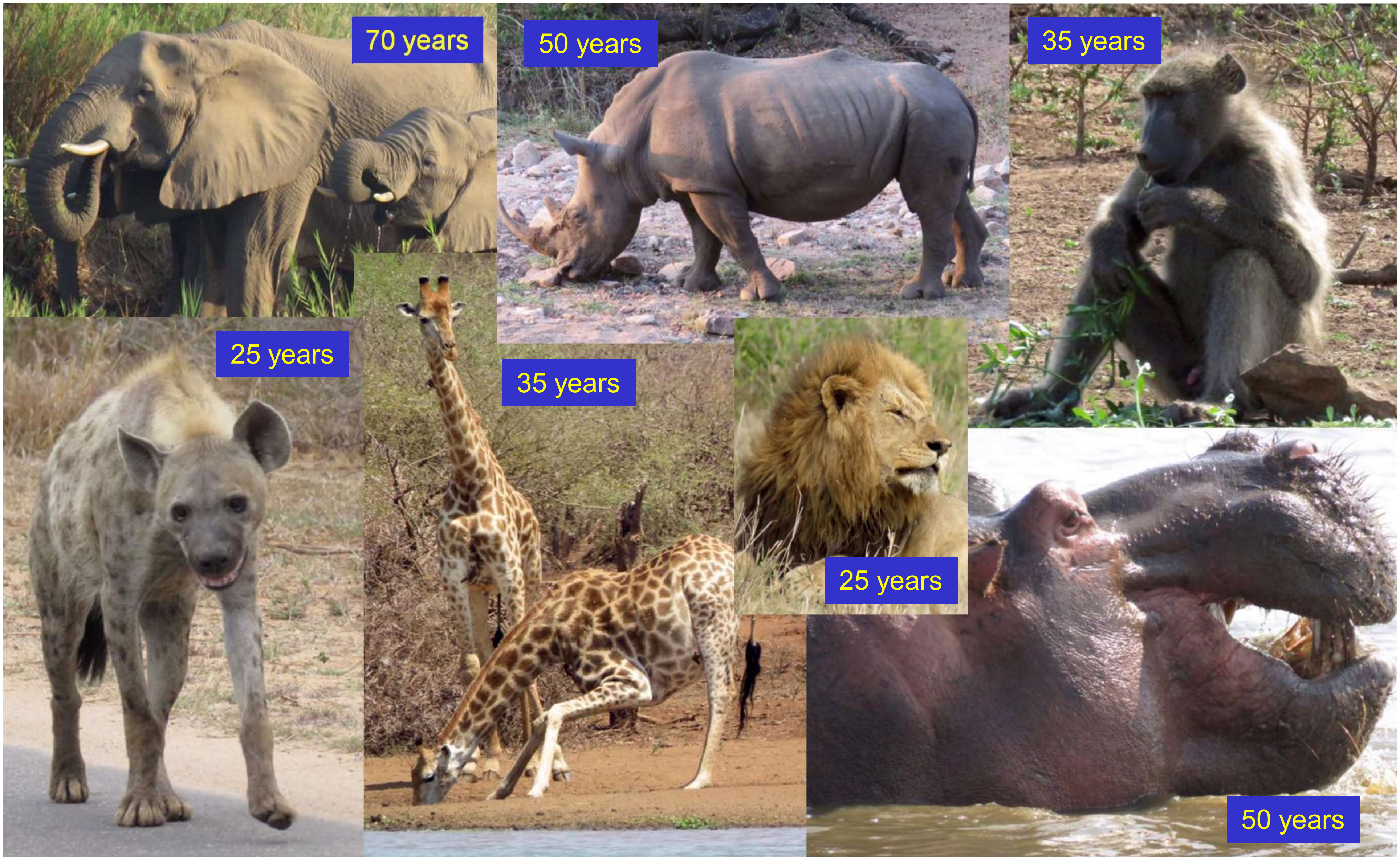




1. Die out
2. Move
3. Stay put

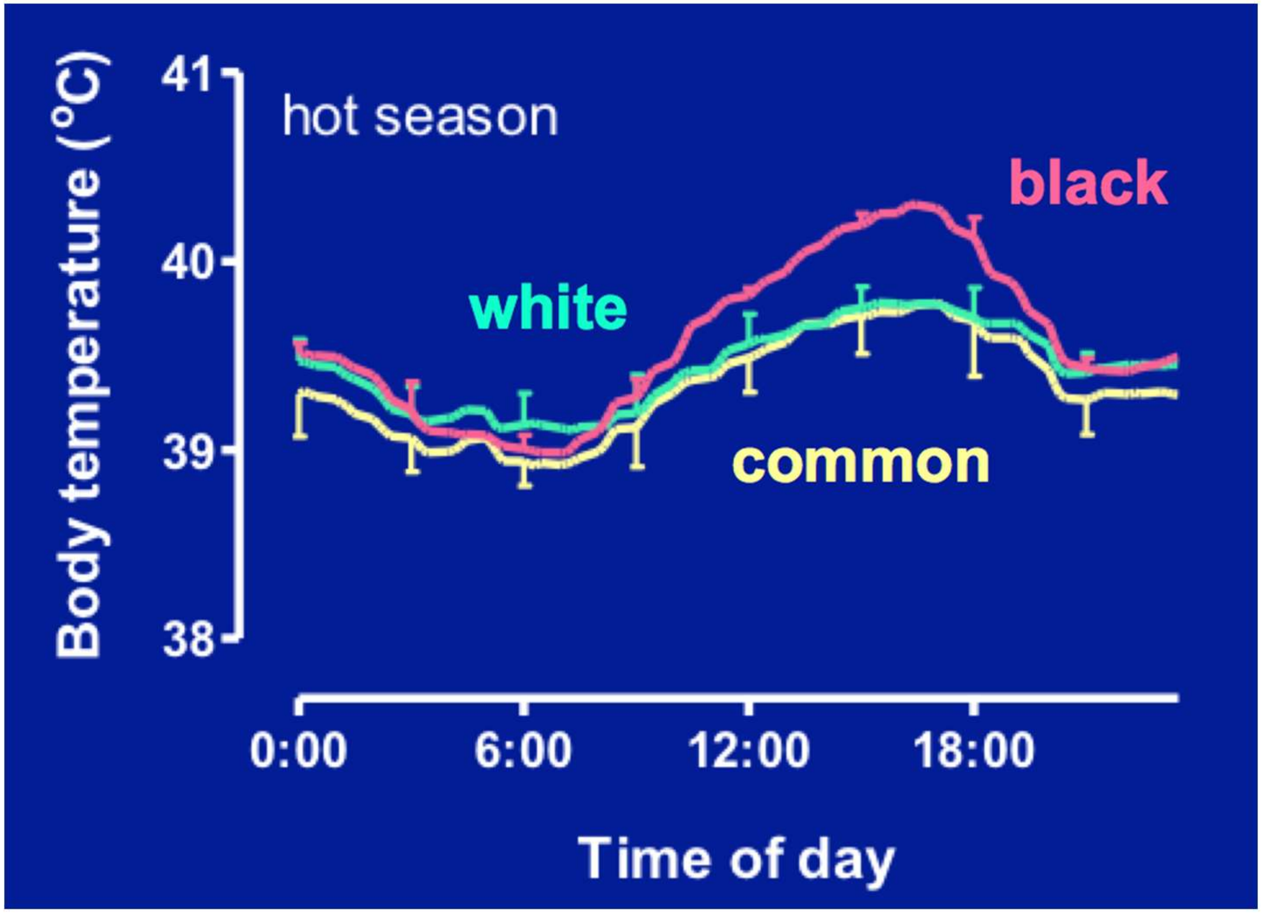
# The “stay-put” options

- **Adaptation**: genetic adjustment occurring by natural selection, and increasing fitness

# How many generations between now and 2050?



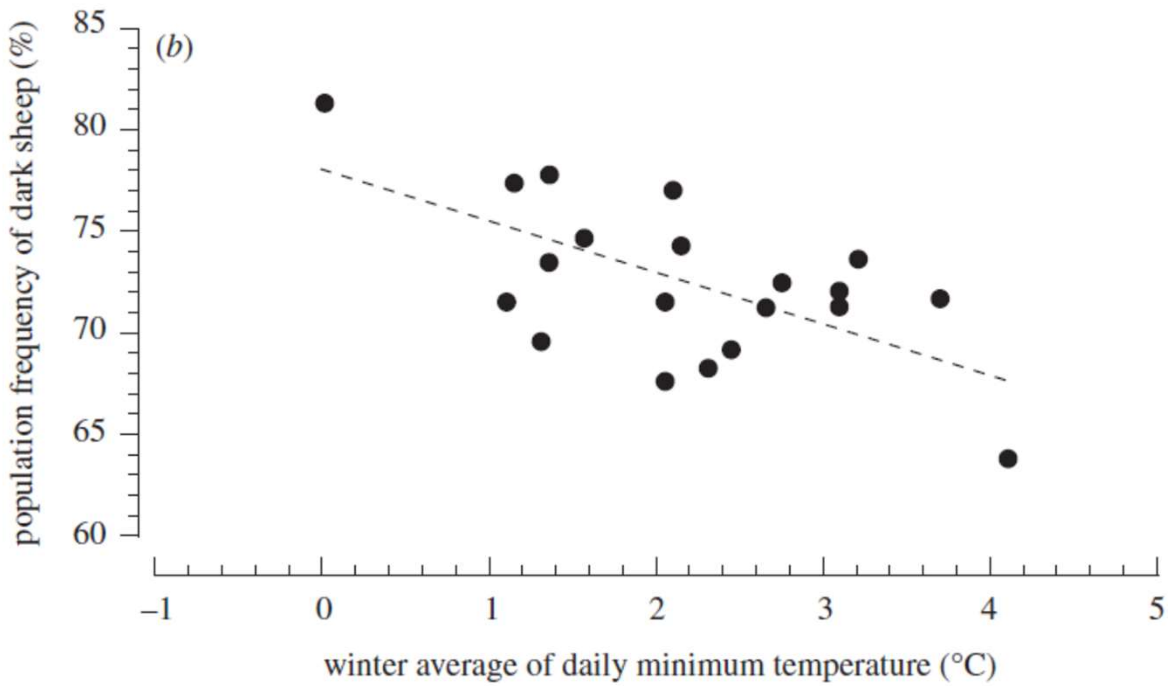
# Microevolution





Hetem et al. *Comp. Biochem. Physiol. A,* 2009

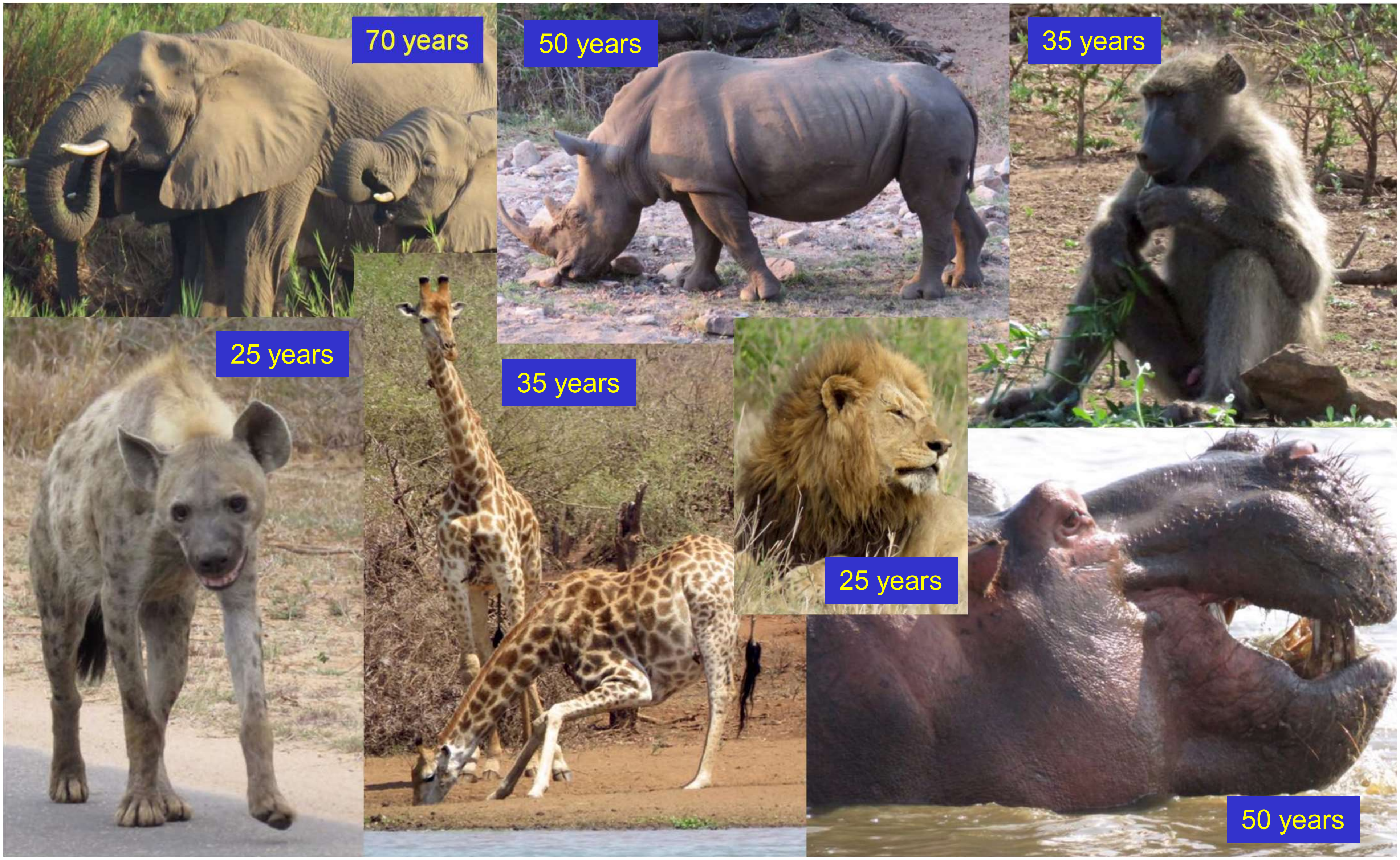
# Soay sheep




Maloney et al. *Biology Letters*, 2009

# Tasmanian devil facial tumour disease

# How many generations between now and 2050?



# The "stay-put" options

- **Acclimatization**: phenotypic adjustment in the natural habitat, to chronic change

# Do animals have latent physiological talents that will help them cope with climate change?

- Free-living animals
- Avoid artefacts caused by human presence
- Long-term field studies
- Identified individual animals
- Characterize microclimates
- Responses of healthy and sick animals

# Do animals have latent physiological talents that will help them cope with climate change?

- Free-living animals
- Avoid artefacts caused by human presence
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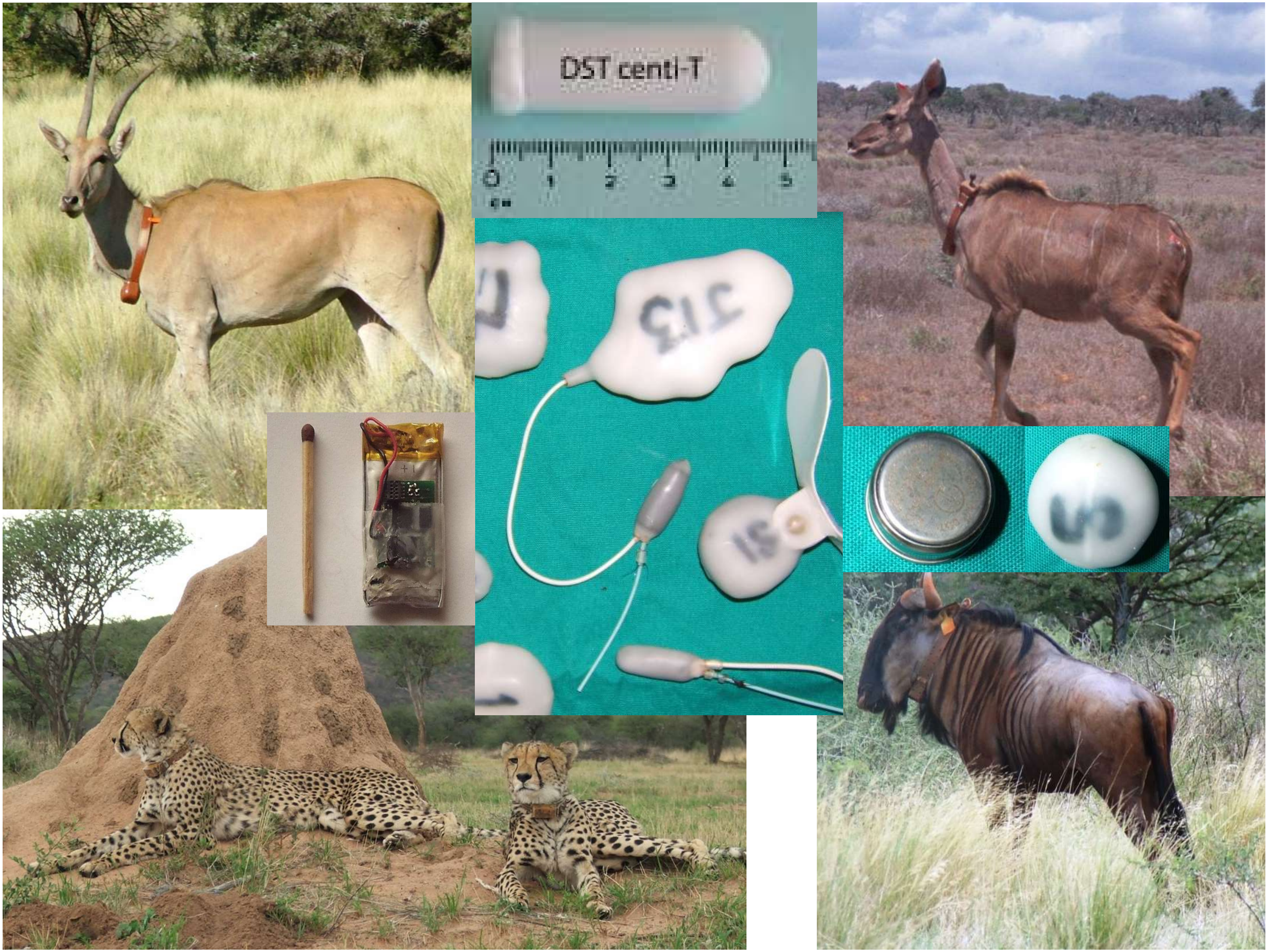
- Characterize microclimates
- Responses of healthy and sick animals

**"Biologging"**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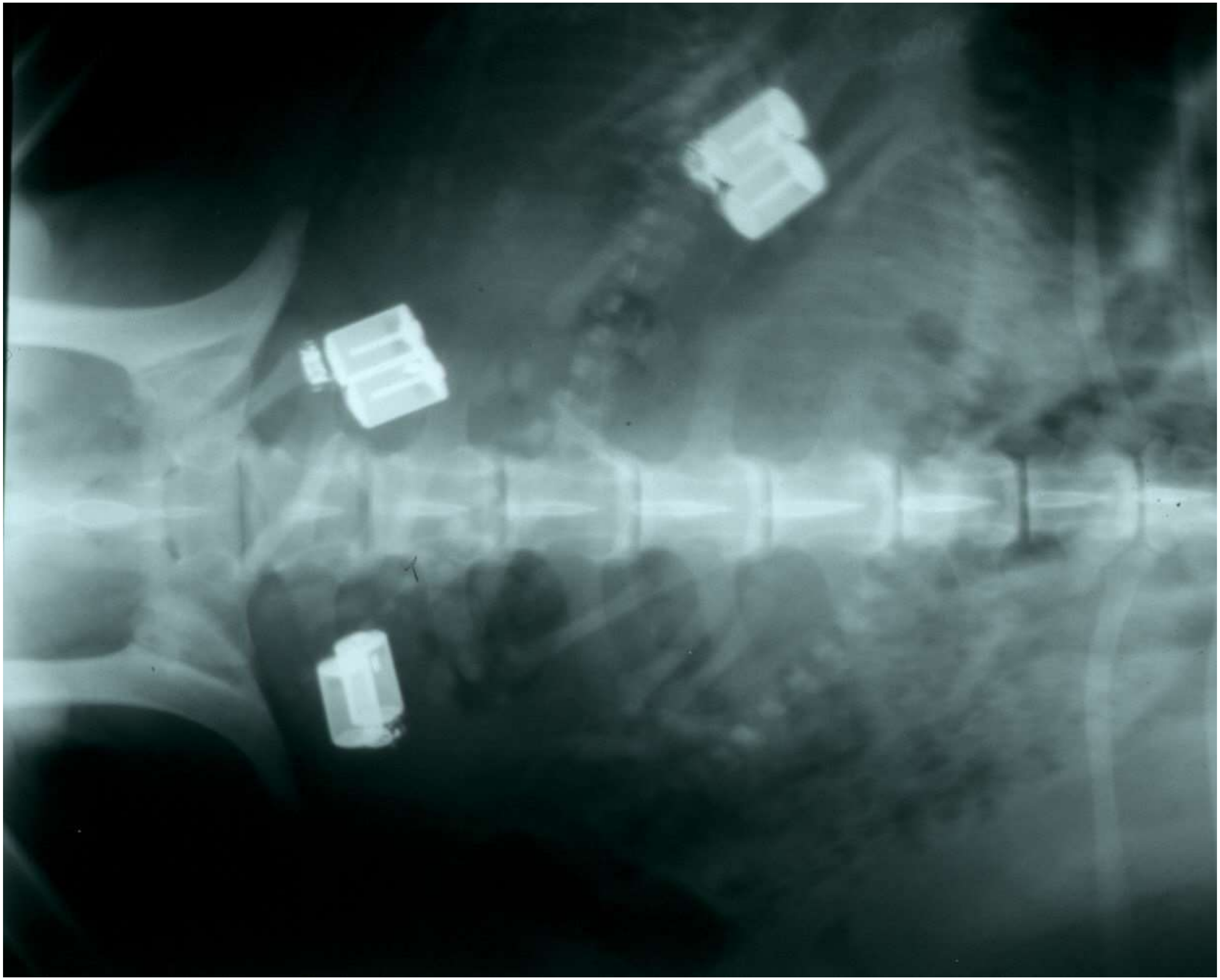
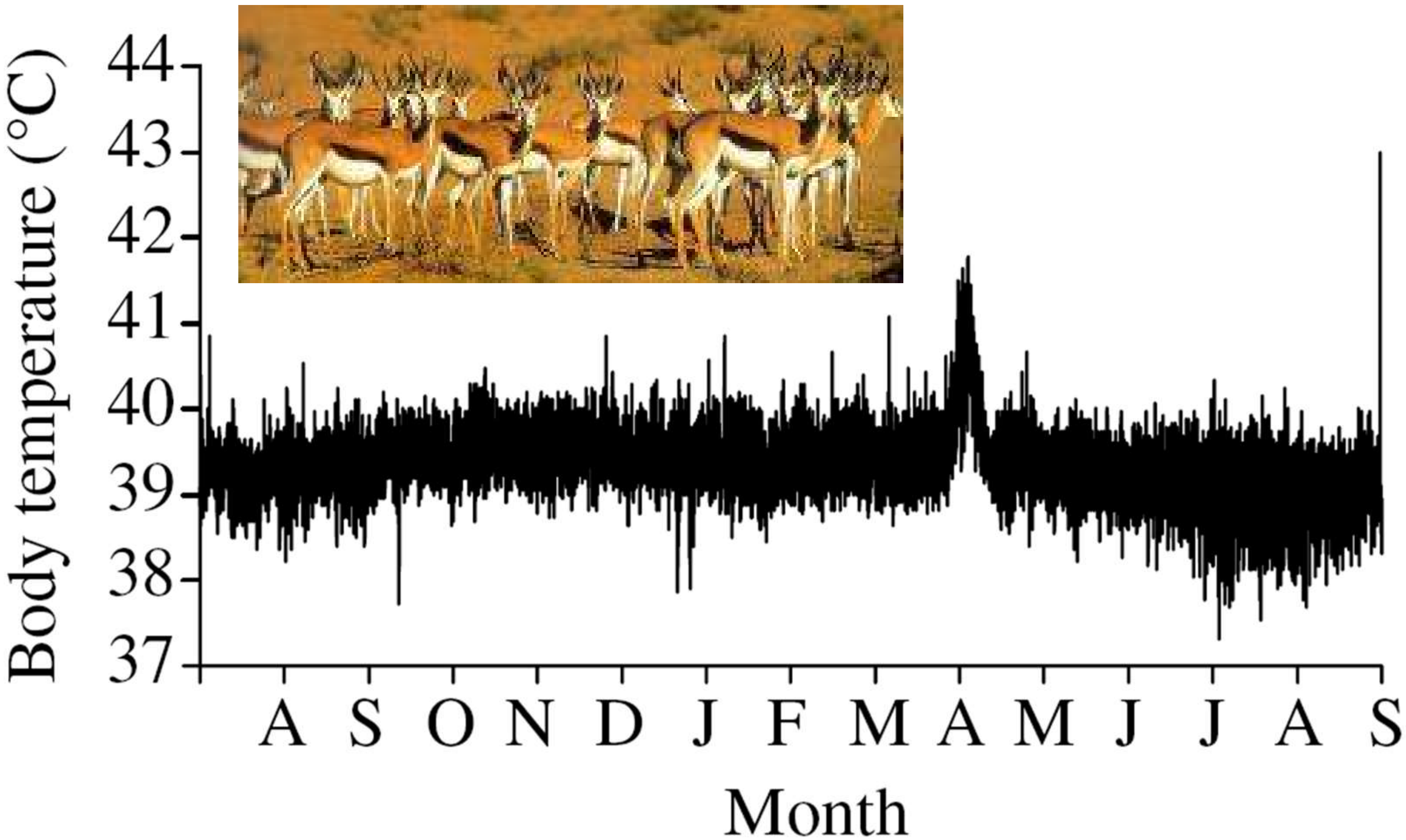
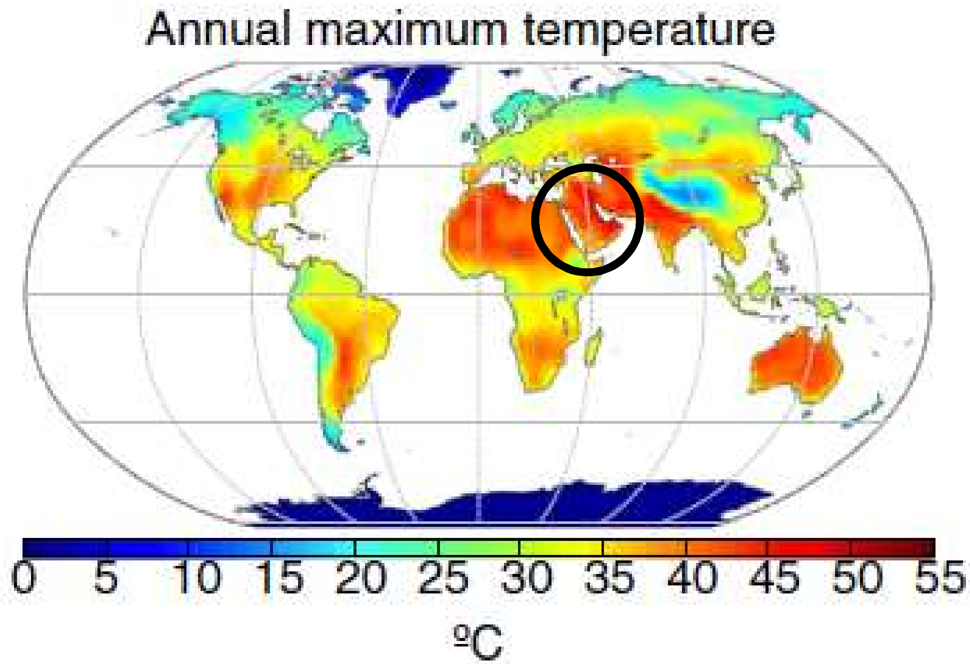
0 1 2 3 4 5



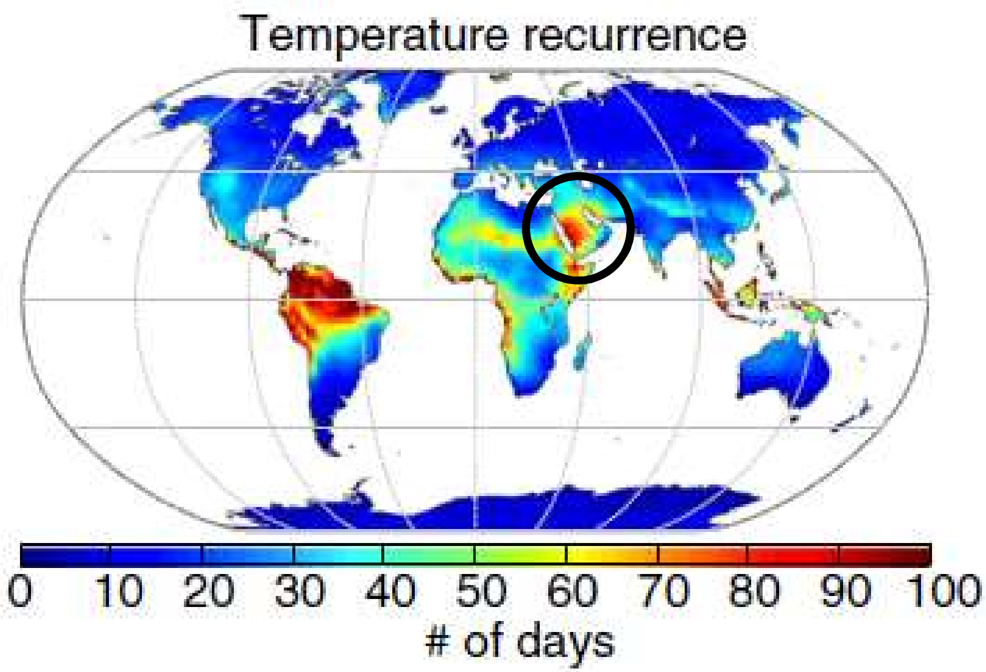
# Year in the thermal life of a springbok




Fuller et al. *Journal of Experimental Biology*, 2005



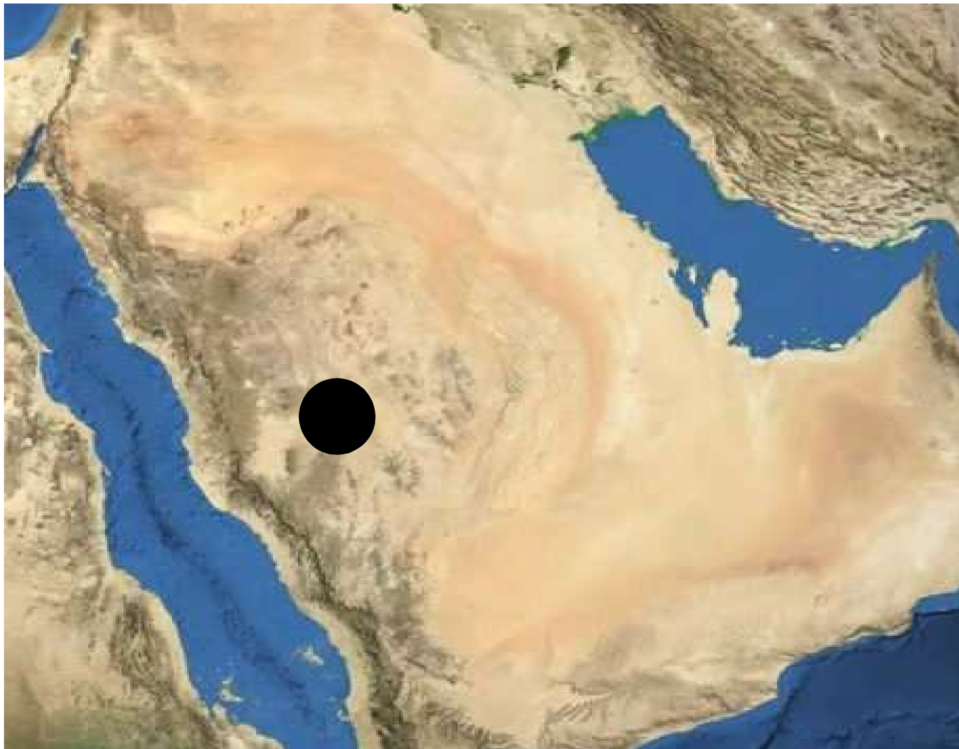

Mean annual maximum air temperature, 1985-2004

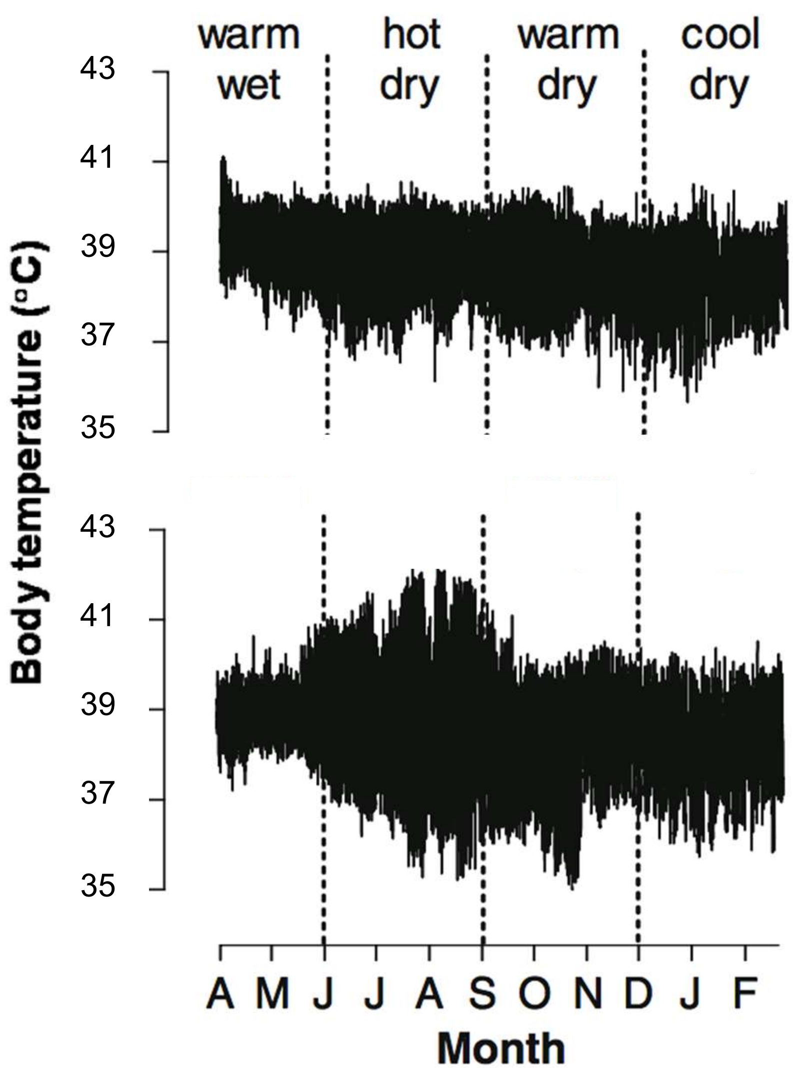



Predicted days per year above those maxima, 2050-2069

Horton et al. *Current Climate Change Reports*, 2016

# Arabian oryx in Saudi Arabia



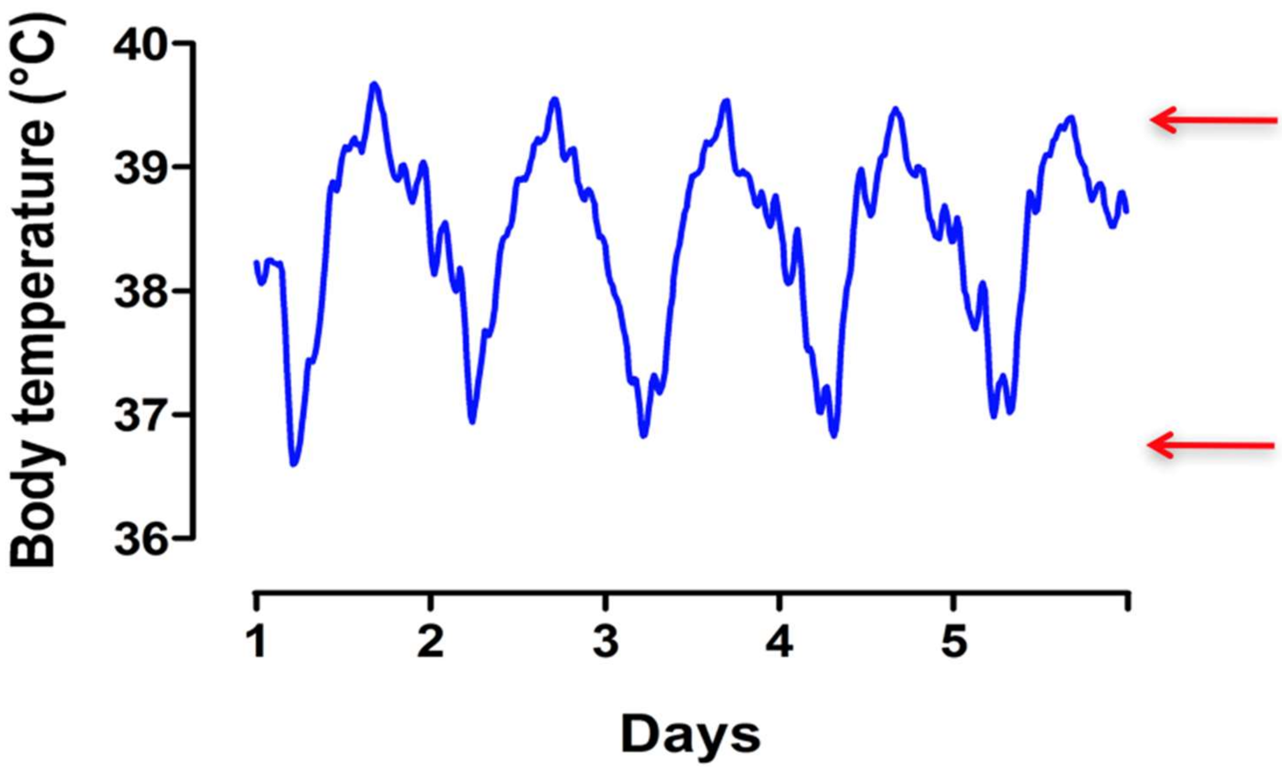



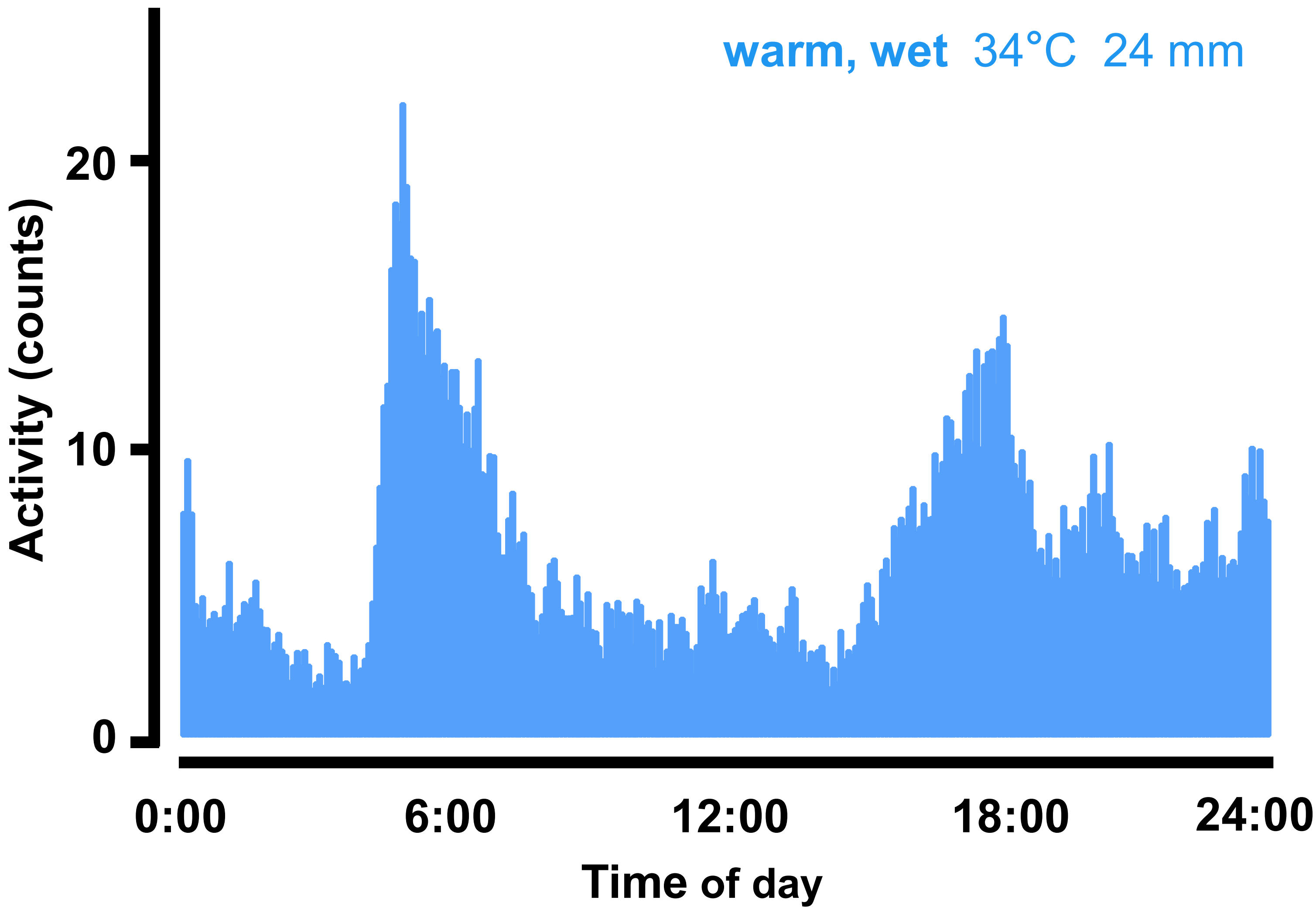

low 24h amplitude
of body temperature
(homeothermy)

high 24h amplitude
of body temperature
(heterothermy)

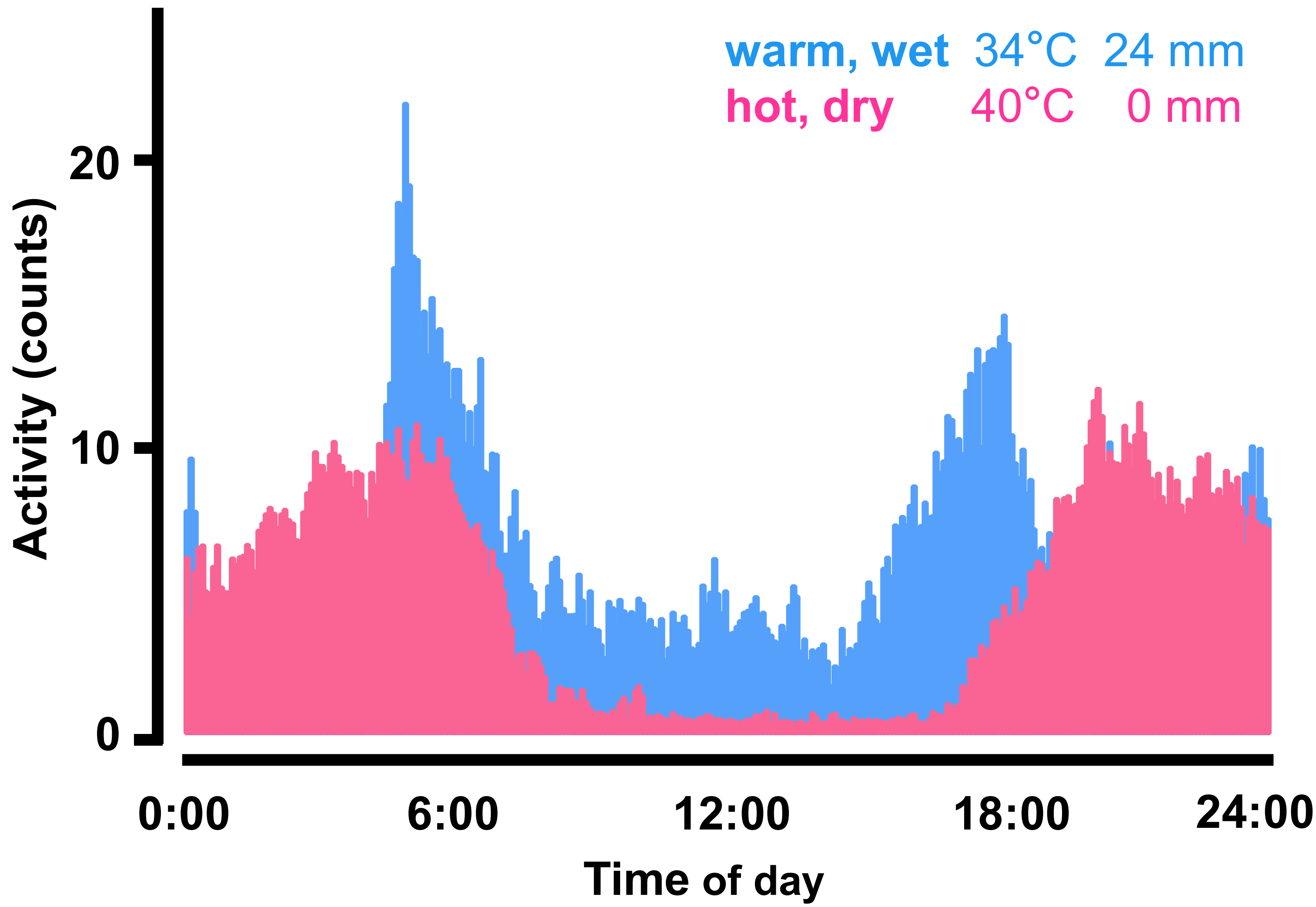
Hetem et al. *Journal of Comparative Physiology B,* 2010

Maintenance of a low amplitude of body temperature (homeothermy) requires energy and water:



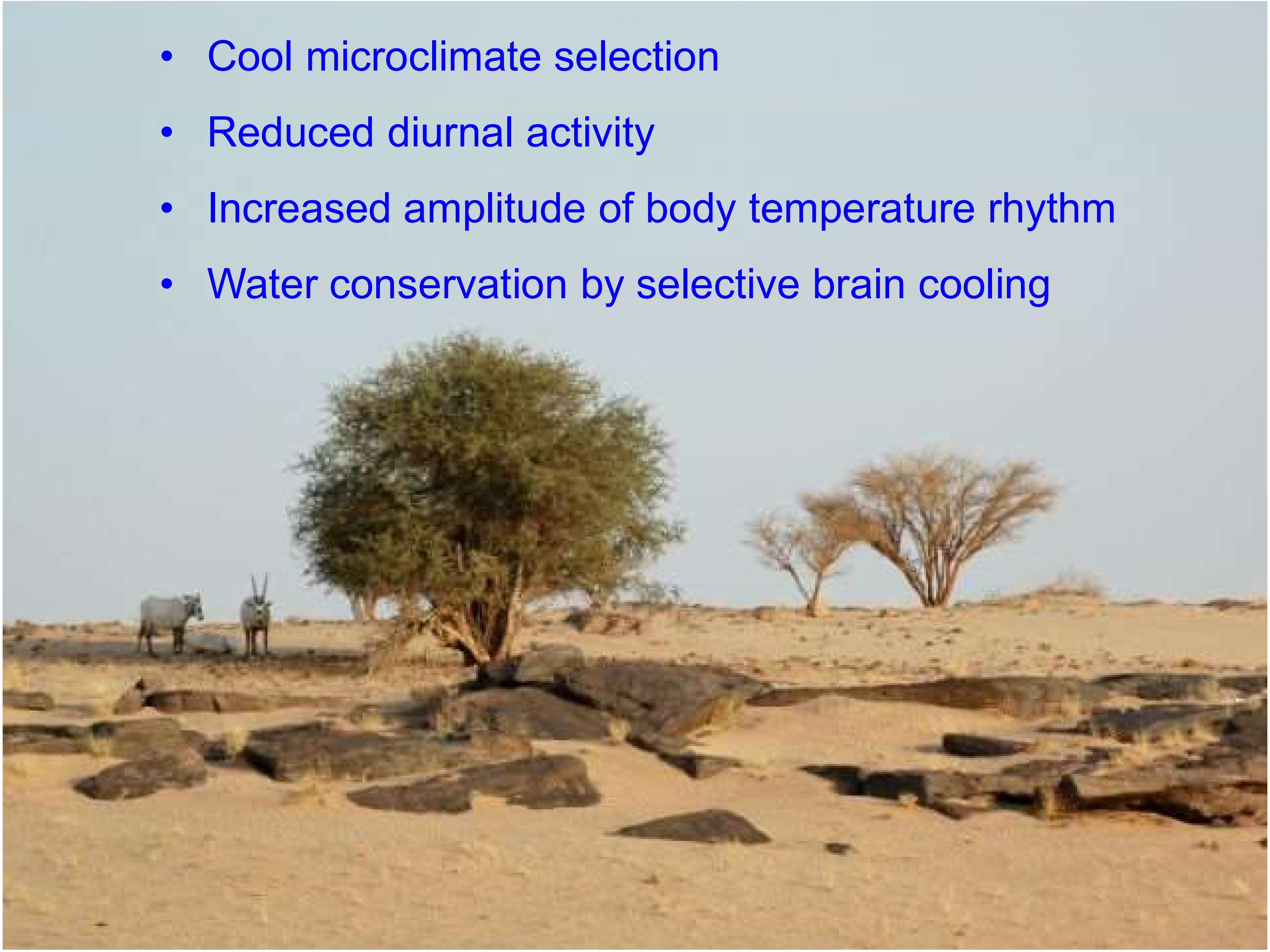

Hetem et al. *Zoology,* 2012




Hetem et al. *Zoology,* 2012

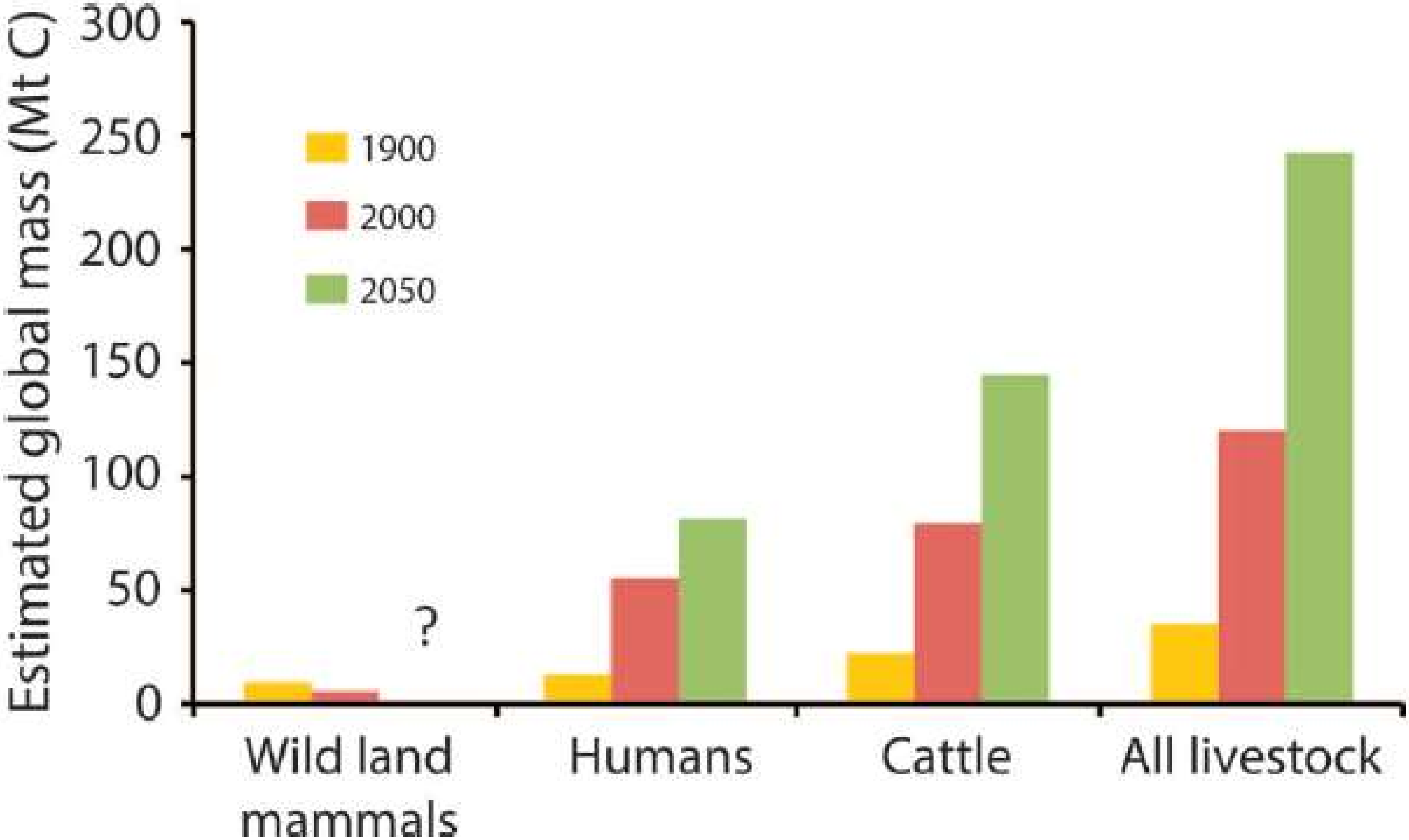
# Moving grazing to the night?

- Cool microclimate selection
- Reduced diurnal activity
- Increased amplitude of body temperature rhythm
- Water conservation by selective brain cooling



Artiodactyls have physiological means of saving water, which they currently don’t need to use fully in most habitats

Perissodactyls have to be near drinking water




Ripple et al. *Science Advances*, 2015

# Projected meat and milk consumption
## (as % of 1980 consumption in the developed world)

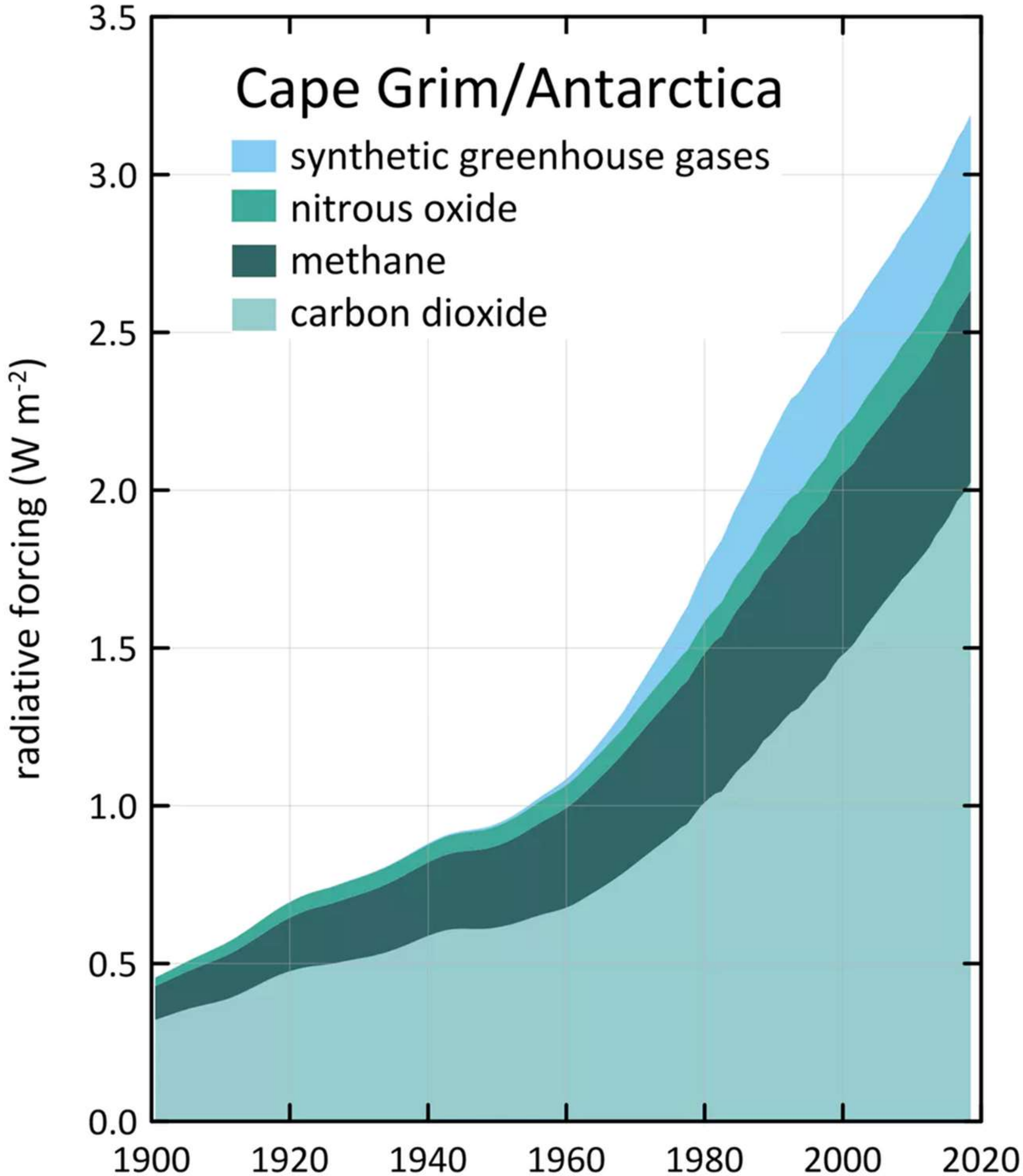
| | Developed | | Developing | |
|---|---|---|---|---|
| | Meat | Milk | Meat | Milk |
| 1980 | 100 | 100 | 55 | 50 |
| 2015 | 130 | 120 | 210 | 140 |
| 2050 | 150 | 130 | 380 | 260 |

Calculated from Table 1 of Thornton P K *Philosophical Transactions of the Royal Society B*, 2010

"Greenhouse gas emissions from ruminant meat production are significant. Reductions in global ruminant numbers could make a substantial contribution to climate change mitigation goals and yield important social and environmental co-benefits"

William J Ripple and colleagues
USA, Scotland, Germany, Australia

Ripple et al. *Nature Climate Change*, 2014



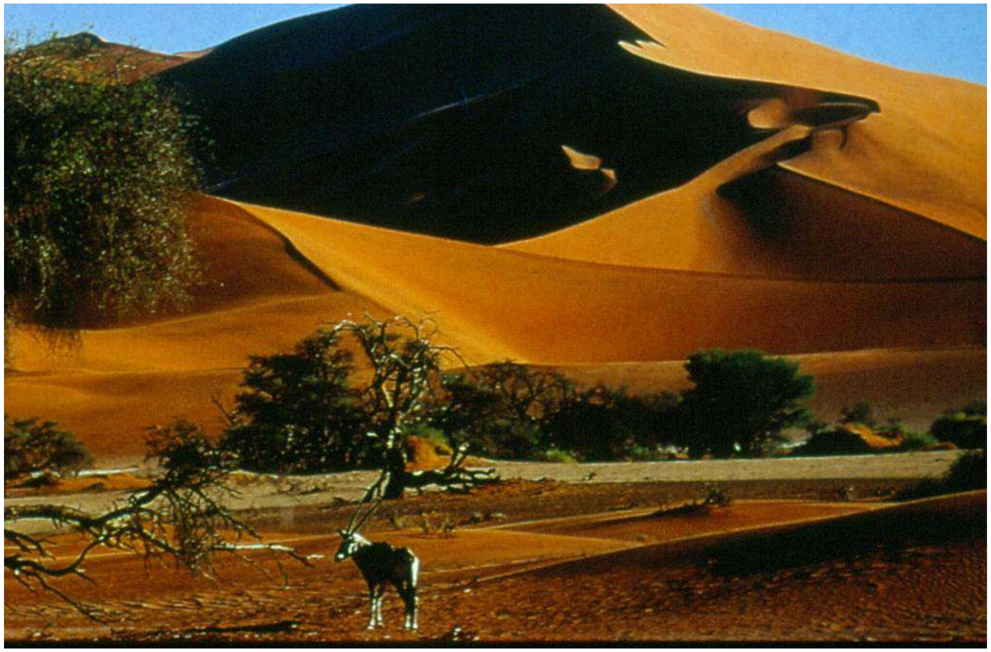

The Conversation 7 June 2019

# Agricultural contributions to greenhouse gas emissions

(as % of anthropogenic sources, with primary source and expectation of change by 2030)

| | | |
|---|---|---|
| Carbon dioxide | 15 | (land use change, stable or decreasing) |
| Methane | 49 | (ruminants and rice, 60% increase in livestock output) |
| Nitrous oxide | 66 | (livestock manure, 35-60% increase) |

Power *Philosophical Transactions of the Royal Society B*, 2010



Central Namib sand sea

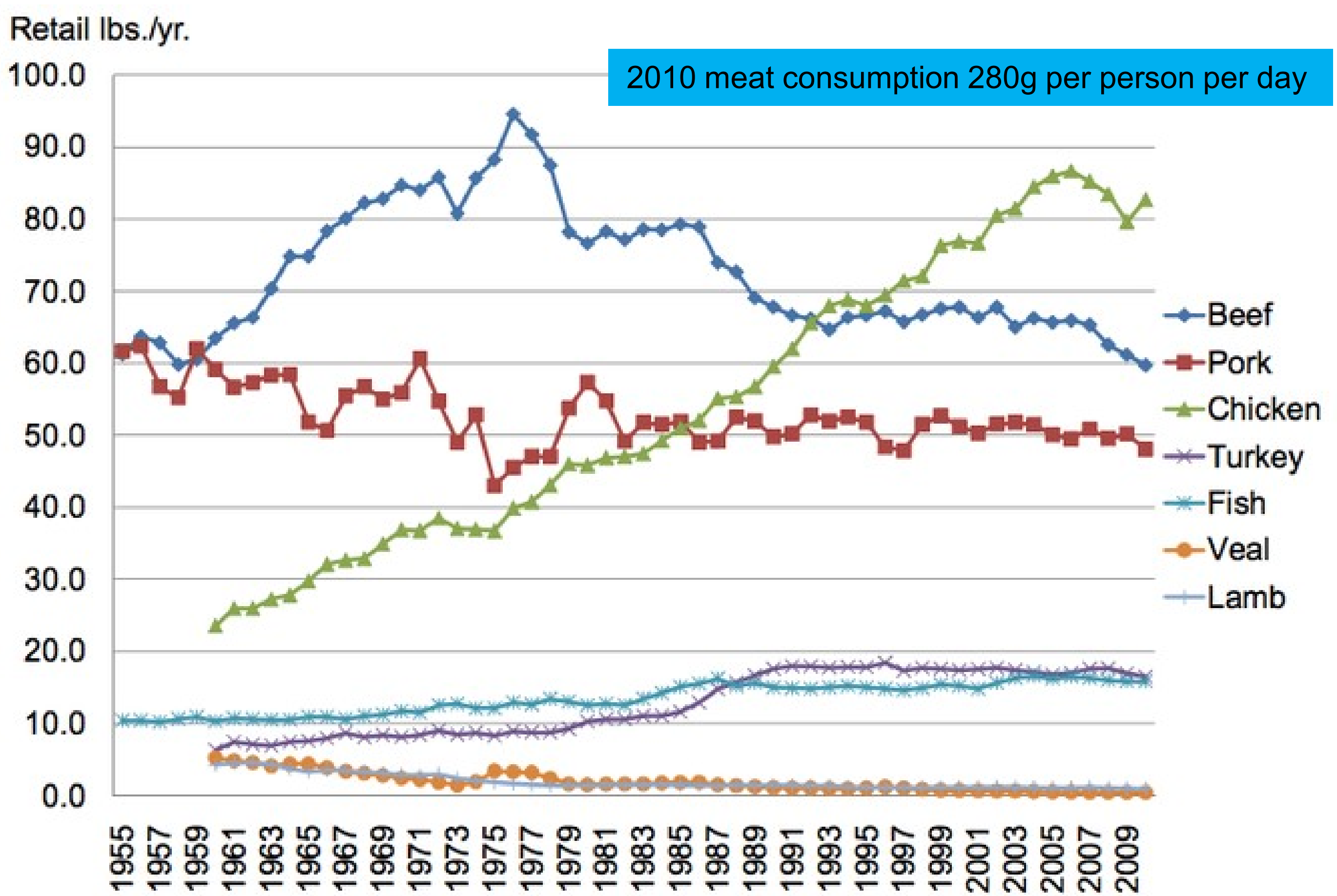
Near Birdsville, Australia

# Litres of water required to produce the human daily requirement (30g) of animal protein

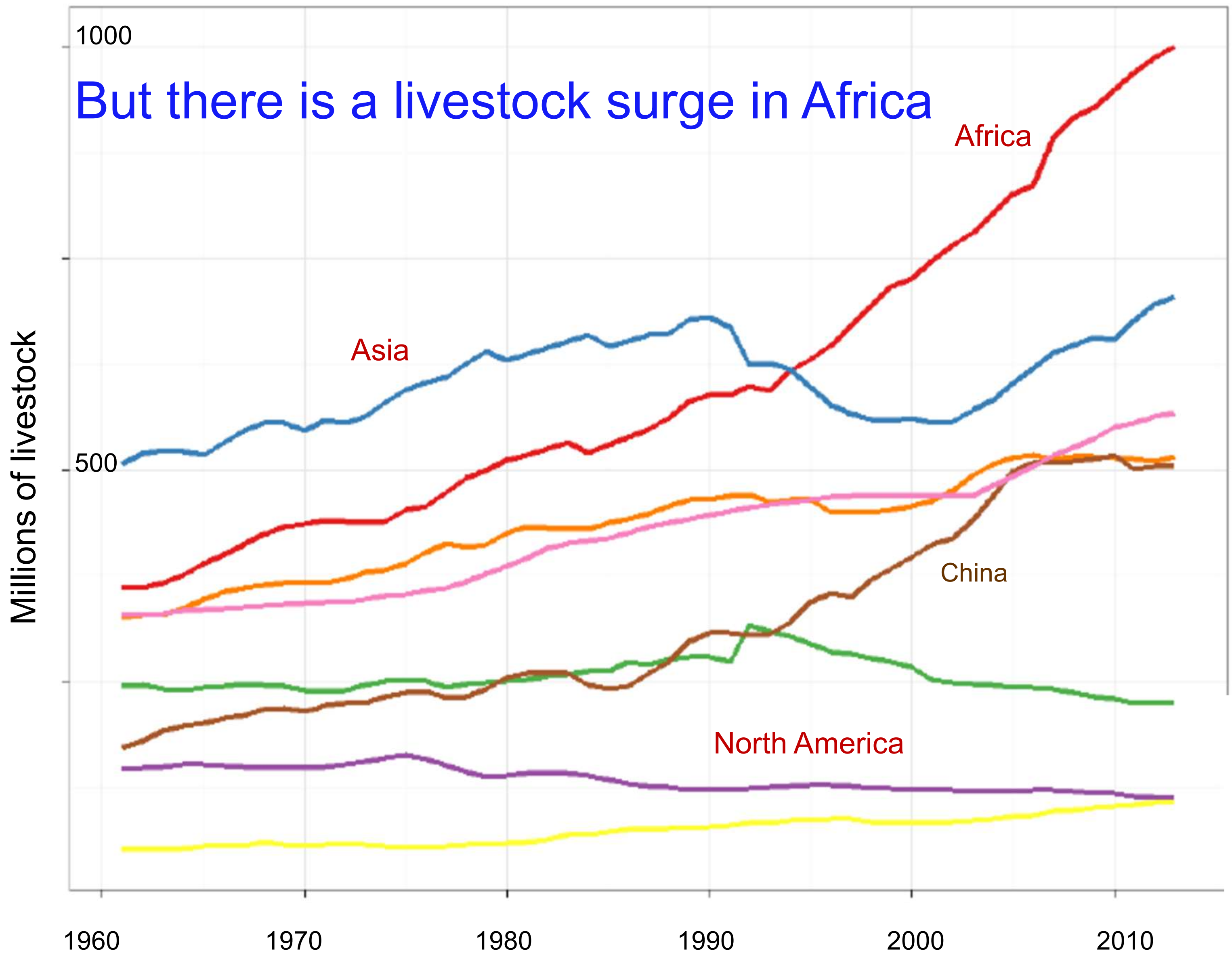
| | |
|---|---|
| Beef | 3700 |
| Mutton | 1900 |
| Pork | 600 |
| | |
| Milk | 700-1900 |

Nardone et al. *Livestock Science*, 2010

# In USA beef consumption is declining

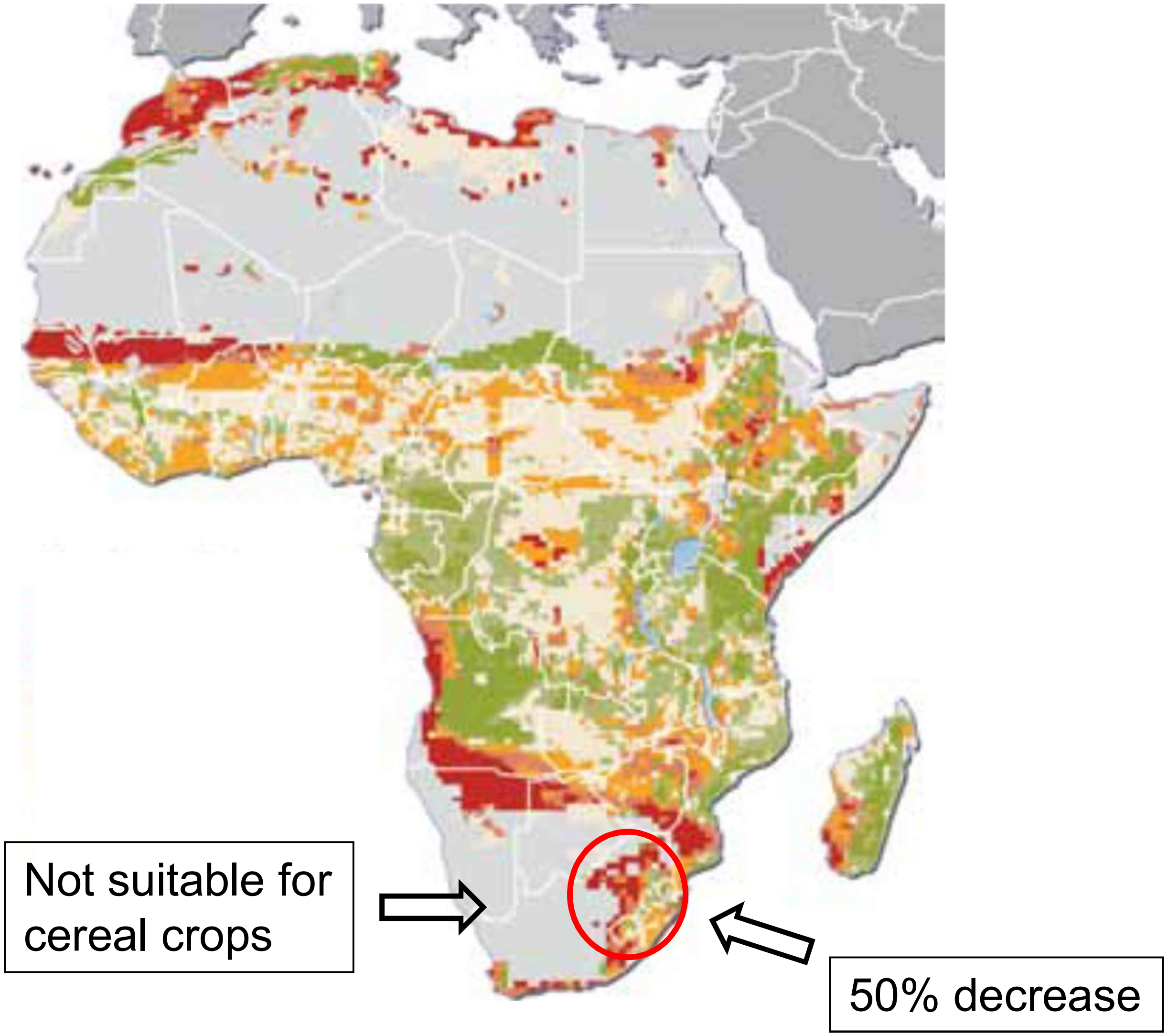



Clive Phillips *The Conversation* 19 May 2015




Ripple et al. *Science Advances*, 2015

# Projected changes in cereal productivity in Africa due to climate change – current climate to 2080




Davis C "Climate change and vulnerability" 2011

# The future for Africa

"African economies are heavily dependent on agriculture. The industry employs 65% of Africa's labour force and accounts for 32% of the continent's overall GDP"

Lahouari Bounoua *The Conversation* 12 May 2015

# The future for Africa

"African economies are heavily dependent on agriculture. The industry employs 65% of Africa's labour force and accounts for 32% of the continent's overall GDP"

## How much does agriculture contribute to South Africa's GDP?

Lahouari Bounoua *The Conversation* 12 May 2015

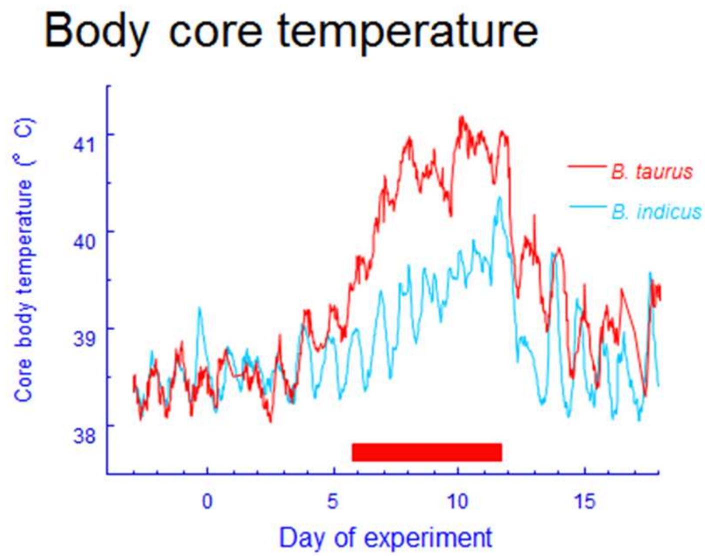
# Agriculture value add (%GDP)

| | 2010 | 2013 |
|---|---|---|
| Mozambique | 29.7 | 29.0 |
| Namibia | 9.3 | 6.1 |
| South Africa | 2.6 | 2.3 |
| Zambia | 10.5 | 9.6 |
| Zimbabwe | 14.5 | 12.0 |
| | | |
| Australia | 2.4 | 2.4 |
| New Zealand | 7.2 | - |
| UK | 0.7 | 0.7 |
| USA | 1.2 | - |

World Bank

## Ambient heat load compromises reproduction by causing:

Failure of conception (male and female effects)
Teratogenesis
Intrauterine growth retardation
Failure of lactation




David Beatty Murdoch University

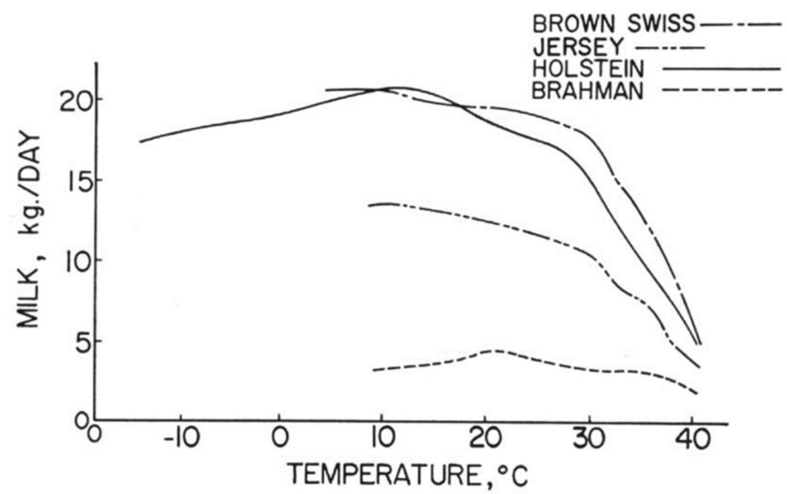



FIG. 6–2. Breed differences in the effect of environmental temperature on milk yield in cattle in controlled temperature laboratory at relative humidity of 40 to 60%. (*Drawn by H. D. Johnson from data by Ragsdale et al., 1950. Mo. Agric. Exp. Sta. Res. Bull. Nos. 471 & 521.*)

From: Hafez (1968). Adaptation of domestic animals

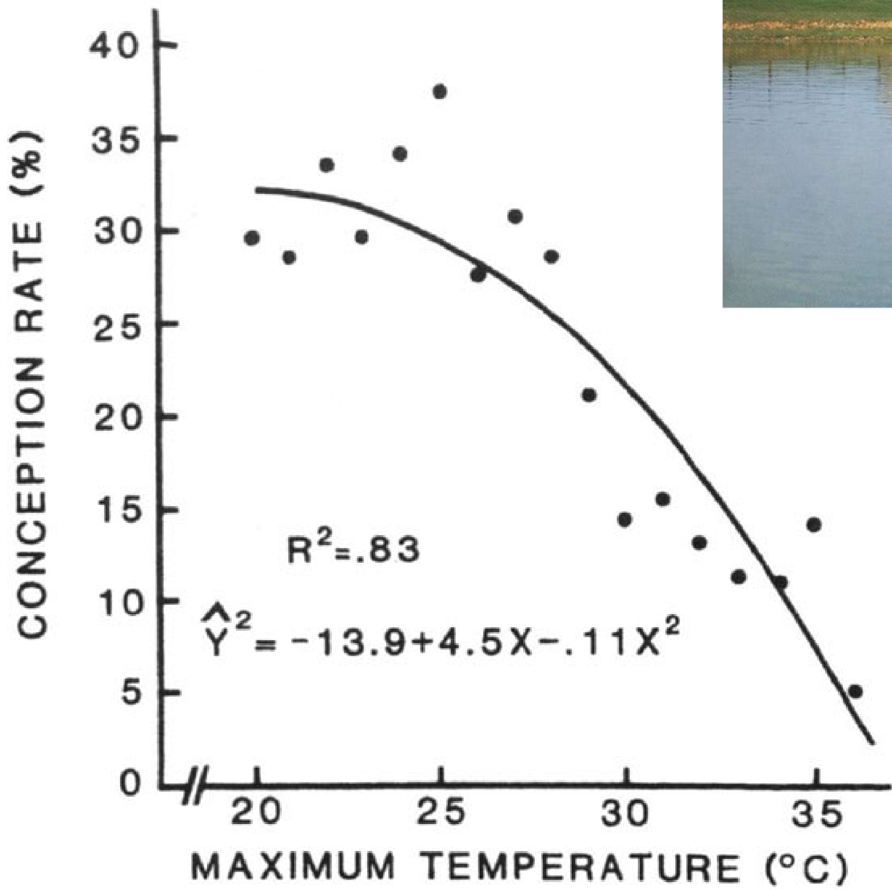
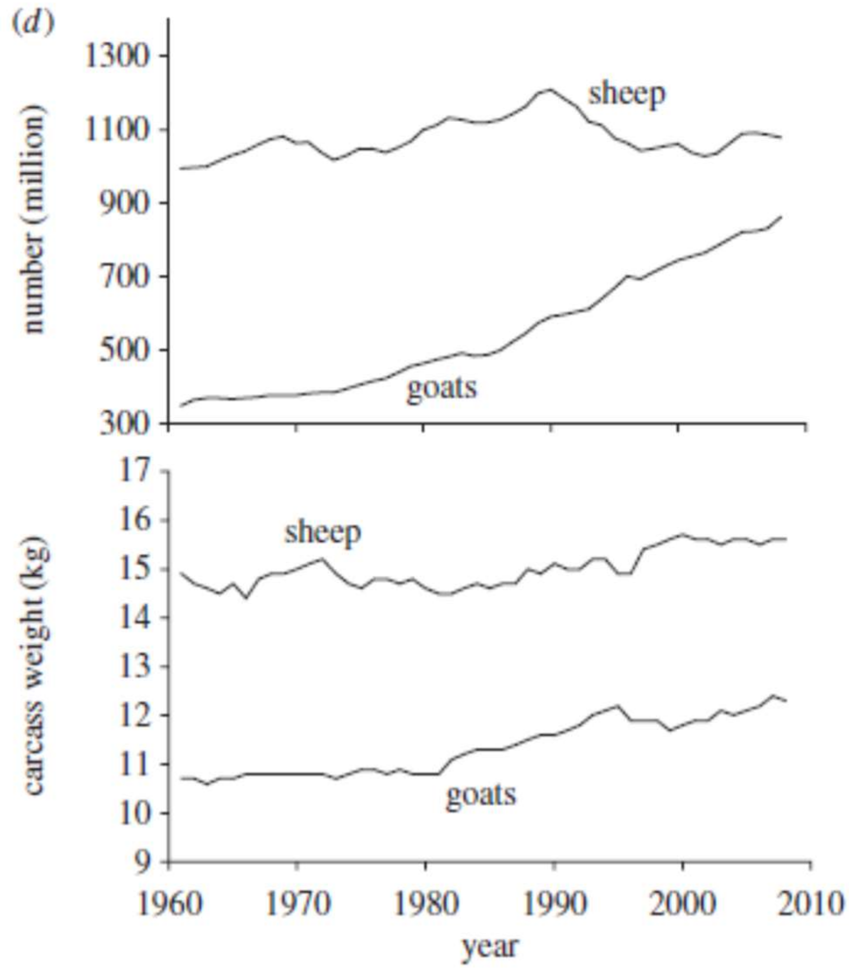



Figure 1. The curvilinear relationship between maximum temperature and conception rate based upon first services grouped according to temperature on the day of breeding.

Cavestany et al. *Journal of Dairy Science*, 1985

# Are goats the future?



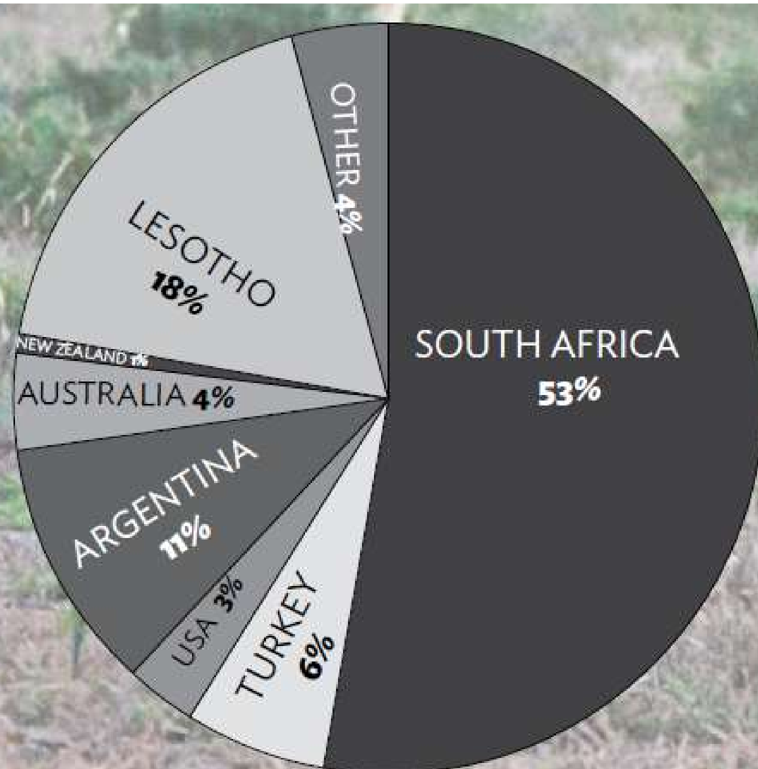

Thornton *Philosophical Transactions of the Royal Society B*, 2010

“Globally, cow milk represents 85% of world production”

But

“it is most probable that more people in the world drink milk or consume dairy products from goats than from any other animal”

Silanikove and Koluman (Darcan) *Small Ruminant Research*, 2015




SHARE OF WORLD PRODUCTION
AANDEEL IN WÊRELD PRODUKSIE

Effects of desertification on the body temperature, activity and water turnover of Angora goats

R.S. Hetem [a,*], B.A. de Witt [a], L.G. Fick [a], A. Fuller [a], S.K. Maloney [b,a], L.C.R. Meyer [a], D. Mitchell [a], G.I.H. Kerley [c]

Hetem et al. *Journal of Arid Environments*, 2011

Per 30g of protein produced, do feedlots or pastoralists contribute more greenhouse gases?

**Funders:**
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Claude Leon Foundation,
START/PACOM,
Tswalu Foundation,
University of the Witwatersrand,
University of Western Australia,
University of Pretoria.

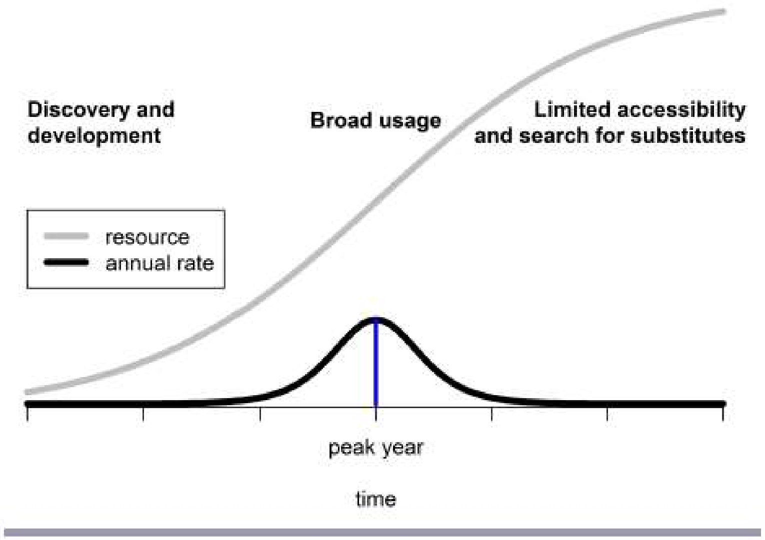

Sir Arnold Theiler Memorial Lecture
Faculty of Veterinary Science
University of Pretoria


Leith


Maartin


Ned

# Peak rates of increase




| | |
|---|---|
| Maize | 1985 |
| Rice | 1988 |
| Wild fish | 1988 |
| Meat | 1996 |
| Milk | 2004 |
| Wheat | 2004 |
| Poultry | 2006 |

| | |
|---|---|
| Cropland | 1950 |
| Irrigated land | 1978 |
| Population | 1989 |

No peak rate yet for:
Coal
Oil
Gas

Seppelt et al. *Ecology and Society*, 2014

# Air temperature thresholds for economic loss

| | |
|---|---|
| Cow in milk | 21°C |
| Dry cow | 24°C |
| Beef cattle | 25°C |
| Shorn sheep | 29°C |
| Dry sow | 30°C |

Da Silva *WMO Guide to Agricultural Meteorological Practices*, 2006.