How large wildlife can contribute to climate change mitigation and adaptation

3 October

Image: Jonas Legarth

wildE Green Shoots

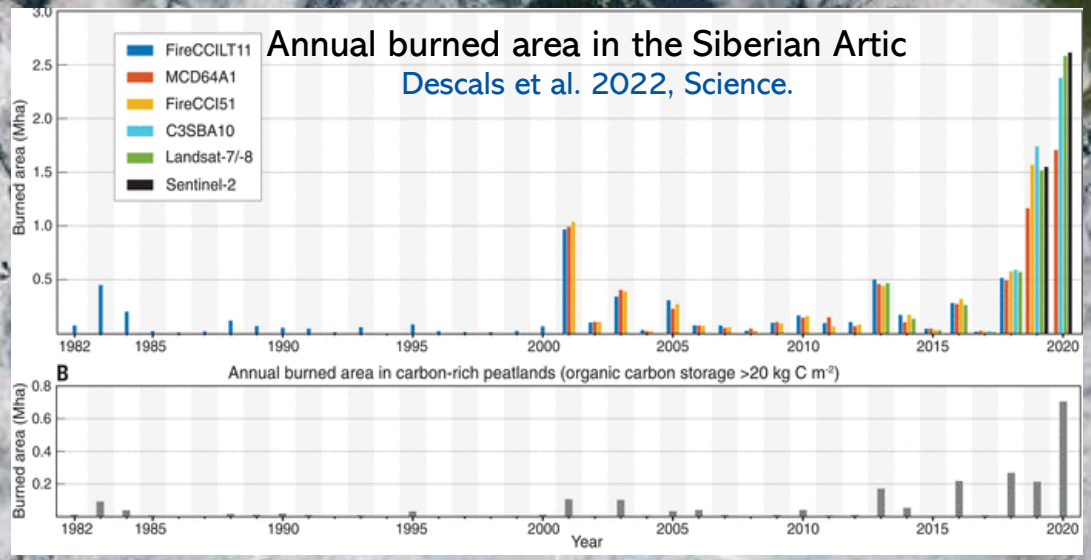
On a highway to hell

Credits: Reuters and Wall Street Journal

Burning the Artic

Russia

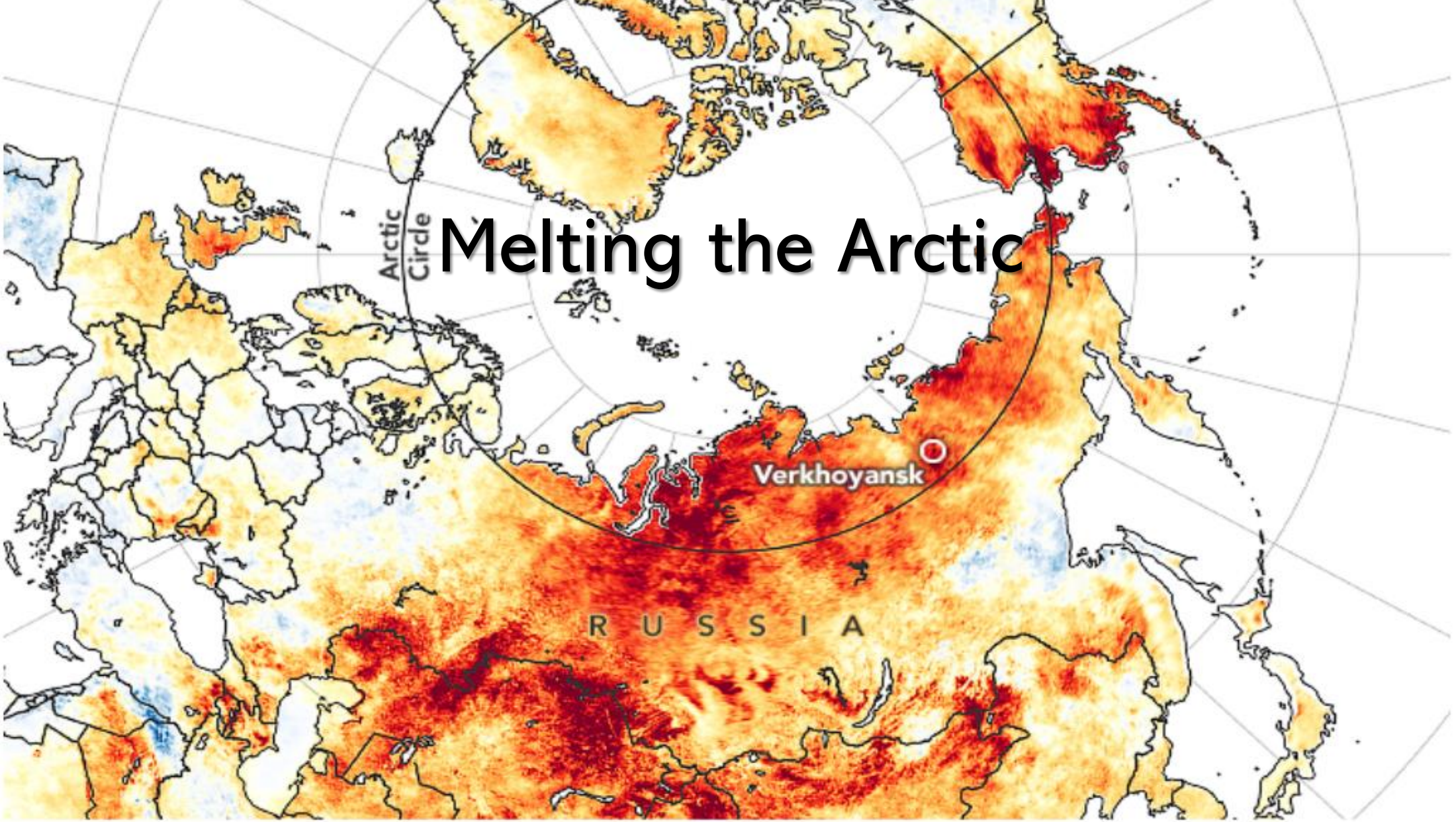
Alaska



Source: Nasa Worldview, 1 Aug 2019

BBC

Melting the Arctic

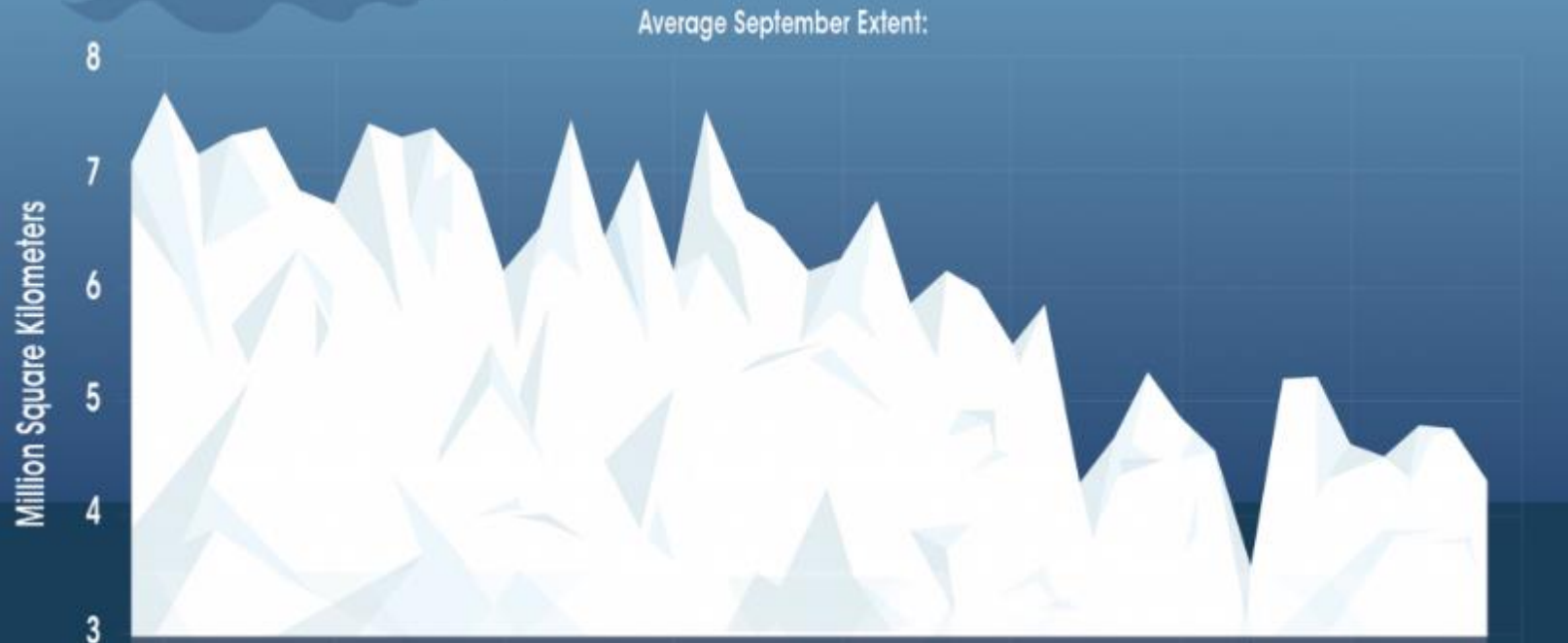


Land Surface Temperature Anomaly (difference from 2003-2018 Spring average, °C)

≤-8 -4 0 4 ≥8

THE INEVITABILITY OF ARCTIC SEA ICE MELTING

The melting of the Arctic's sea ice has been a reality for decades. However, a recent study by UCLA climate scientists has found that the ice will disappear sooner than previously thought – the Arctic Ocean may be ice-free for part of the year at some point between 2044 and 2067.

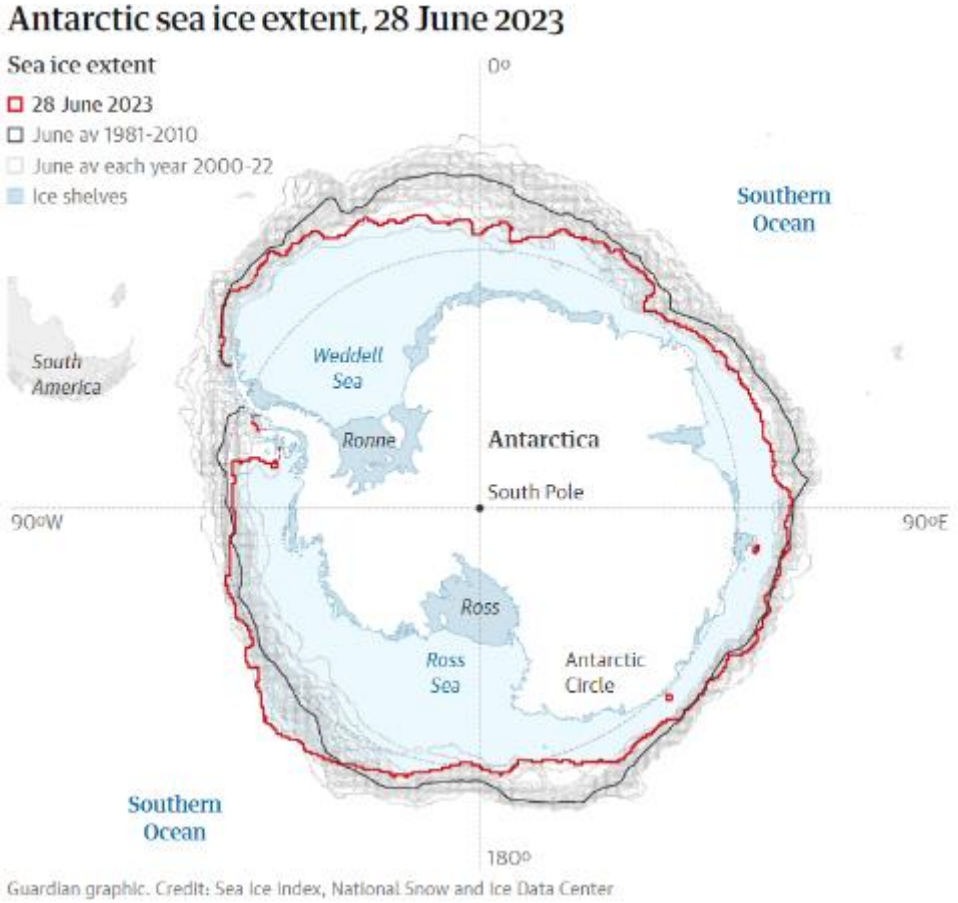


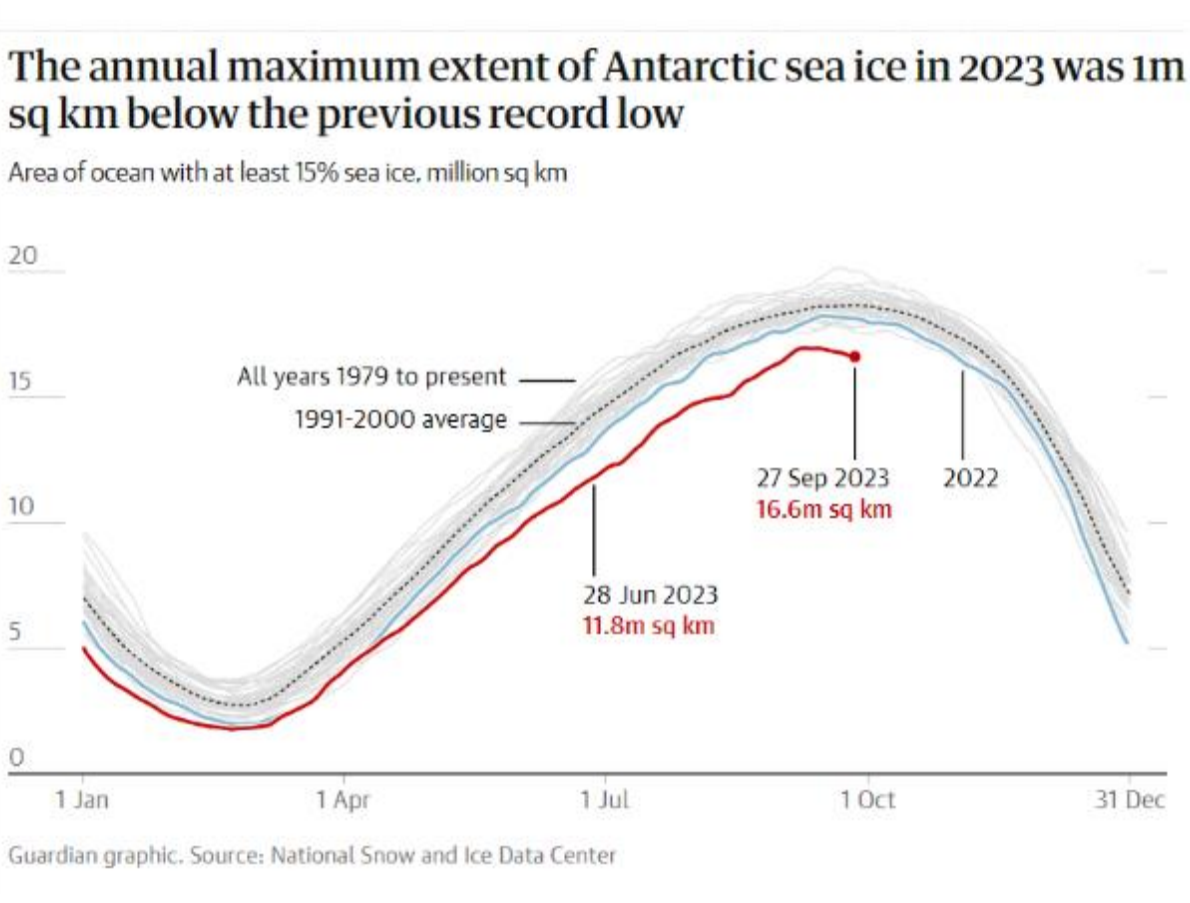
Rate of Change:

↓12.85%

per decade

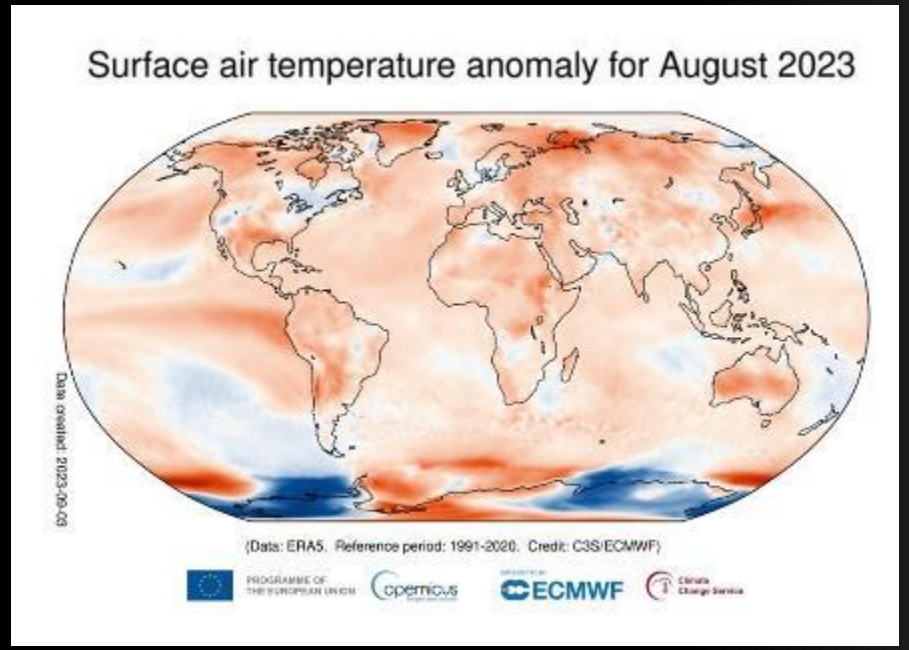
SOURCES: UCLA Newsroom, NASA. Graphic reporting by Sameera Pant. Graphic by Claire Guo, Daily Bruin contributor.

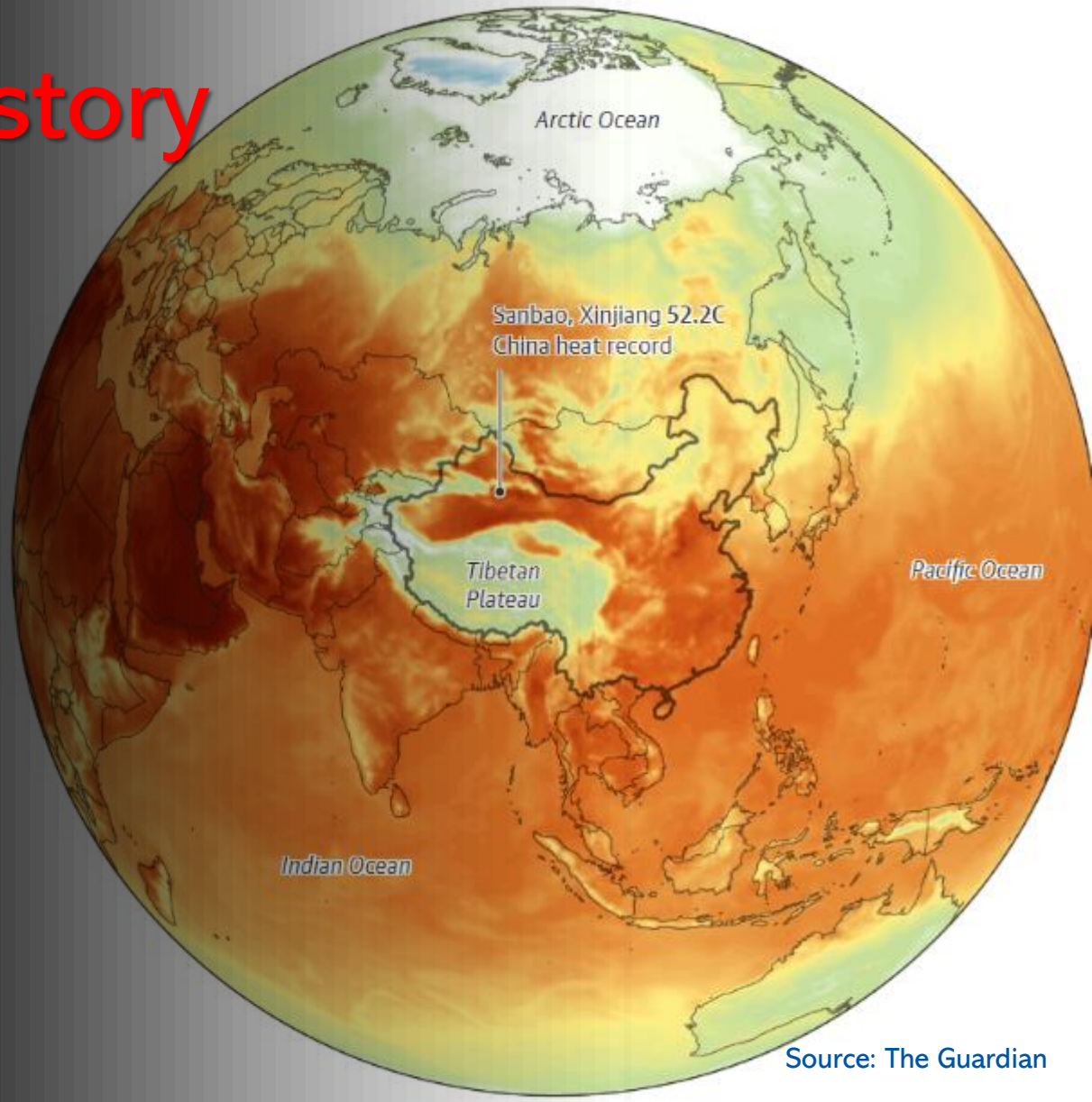




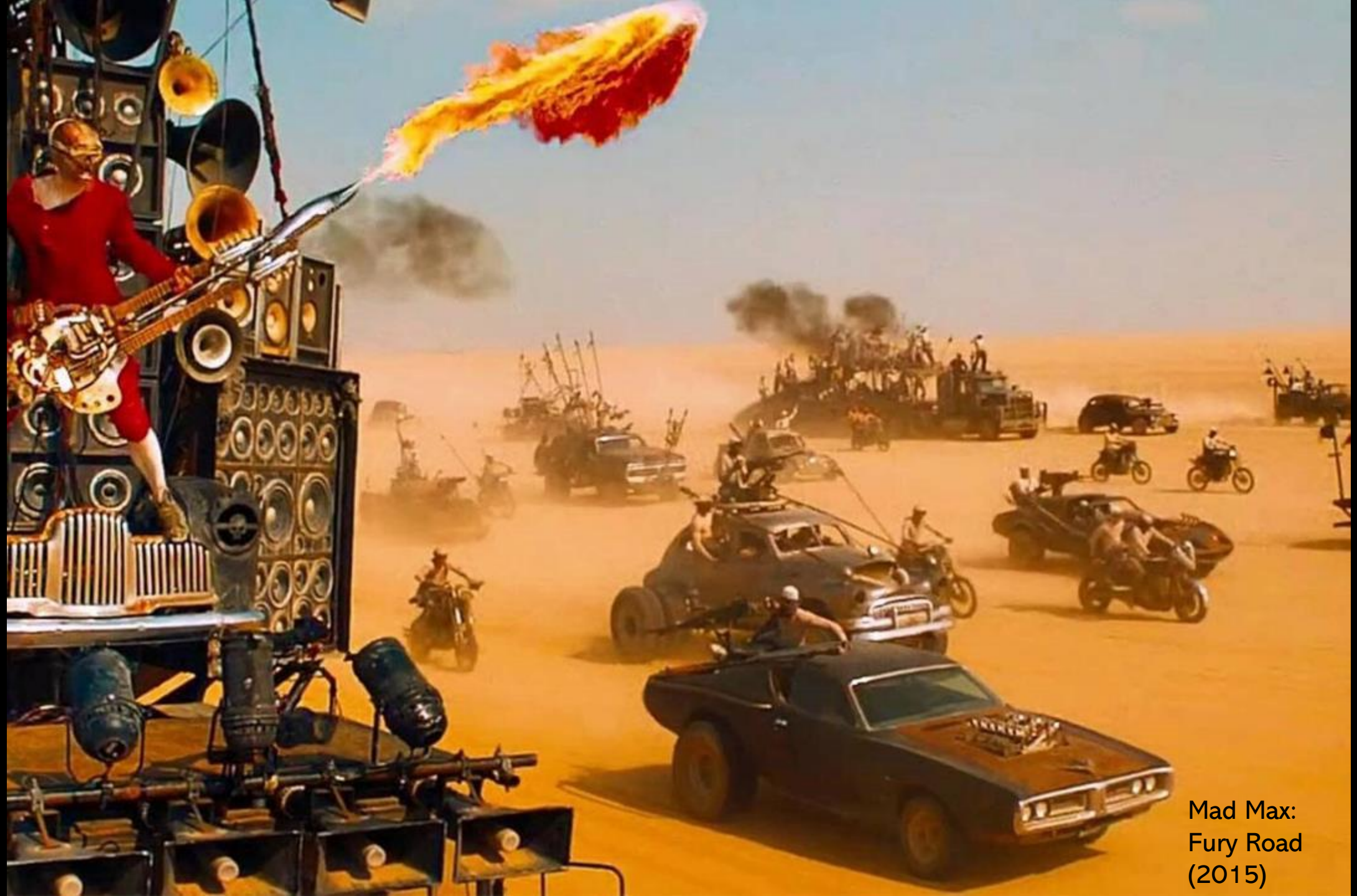
Melting the Antarctic

The hottest summer in history





Source: The Guardian

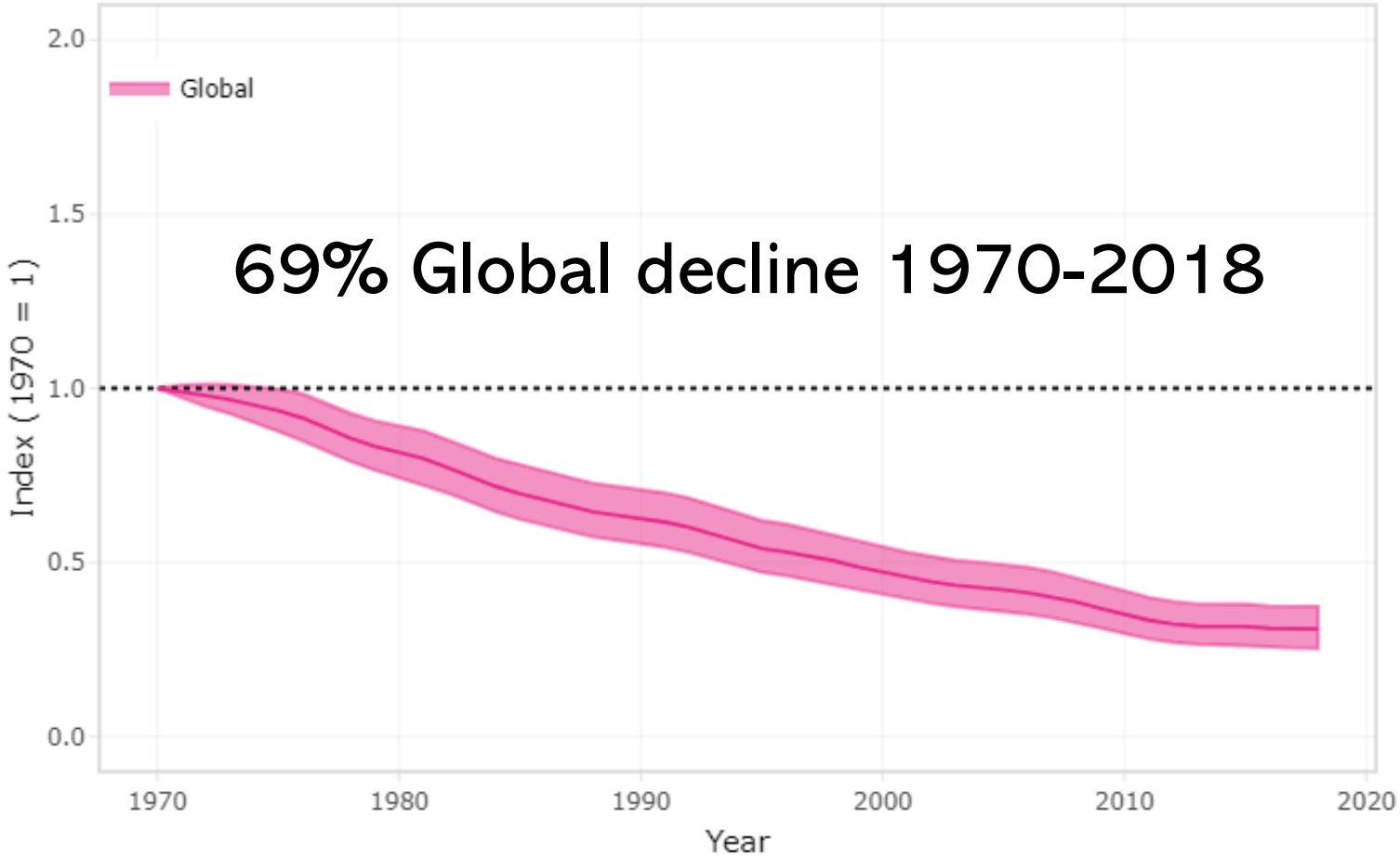


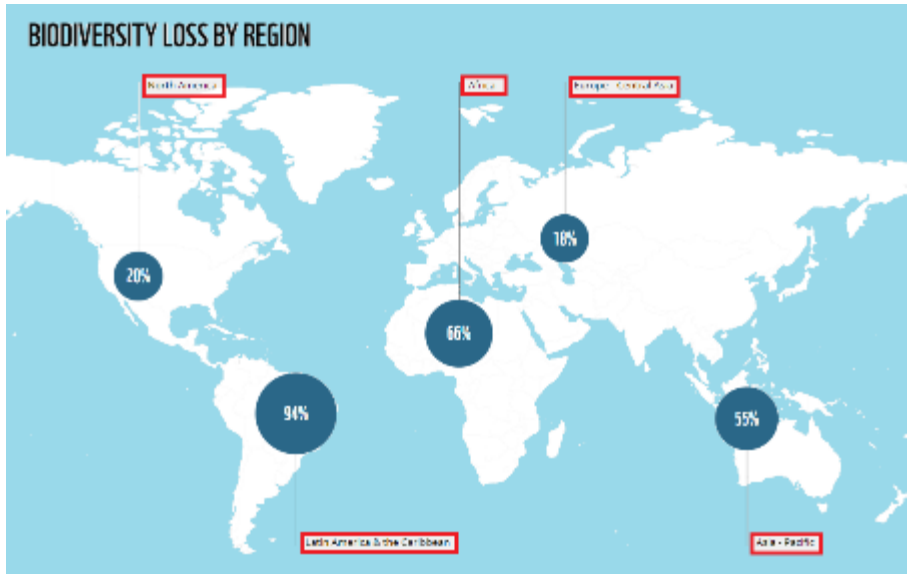
Mad Max:
Fury Road
(2015)

Can wildlife help us with Climate Change?

Credit: Steve Bloom Images Alamy

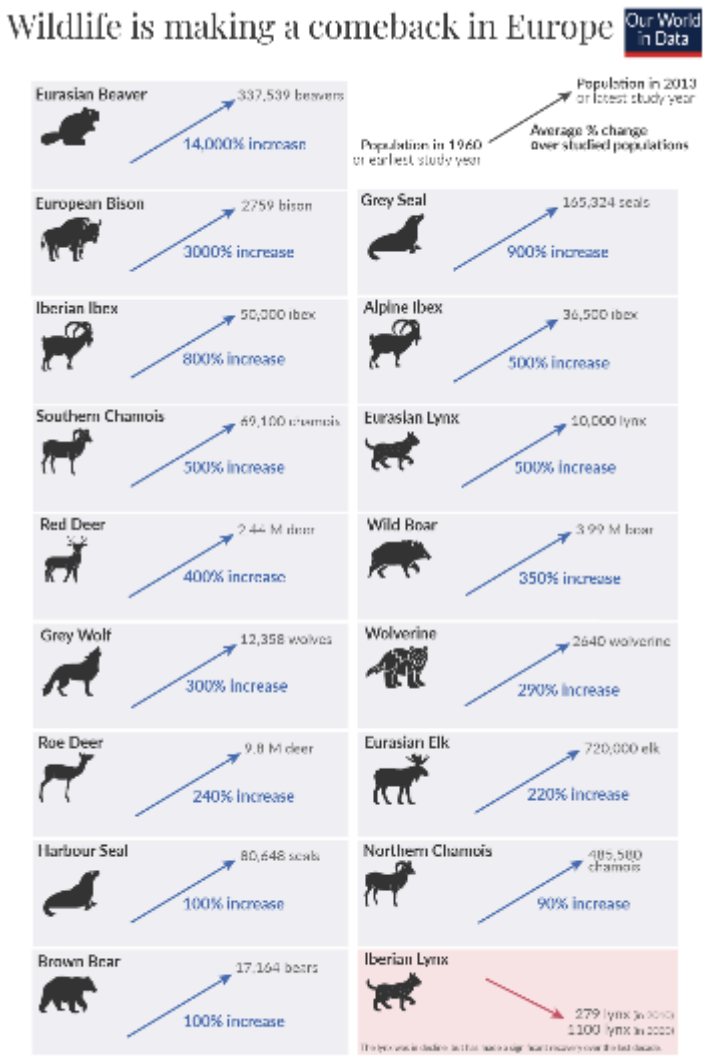
Wildlife declines





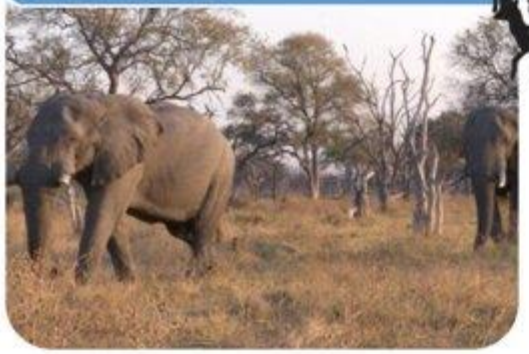
Data: Living Planet Report 2022 (monitored vertebrate populations), WWF/ZSL

…..and comebacks



Near-intact ecosystems

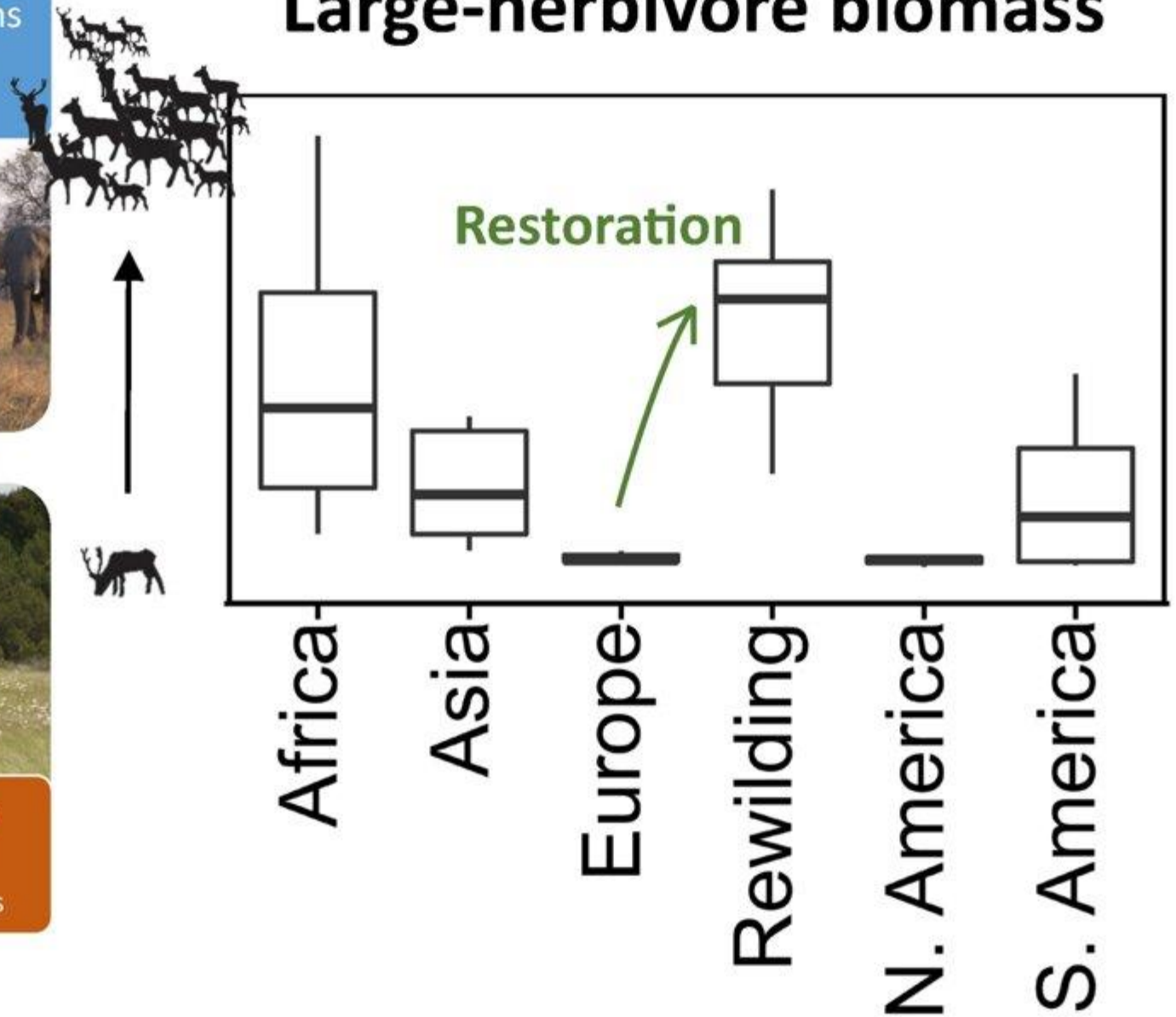
- Natural baseline for large-herbivore biomass



Degraded ecosystems

- Lower than expected biomass of large herbivores

Large-herbivore biomass

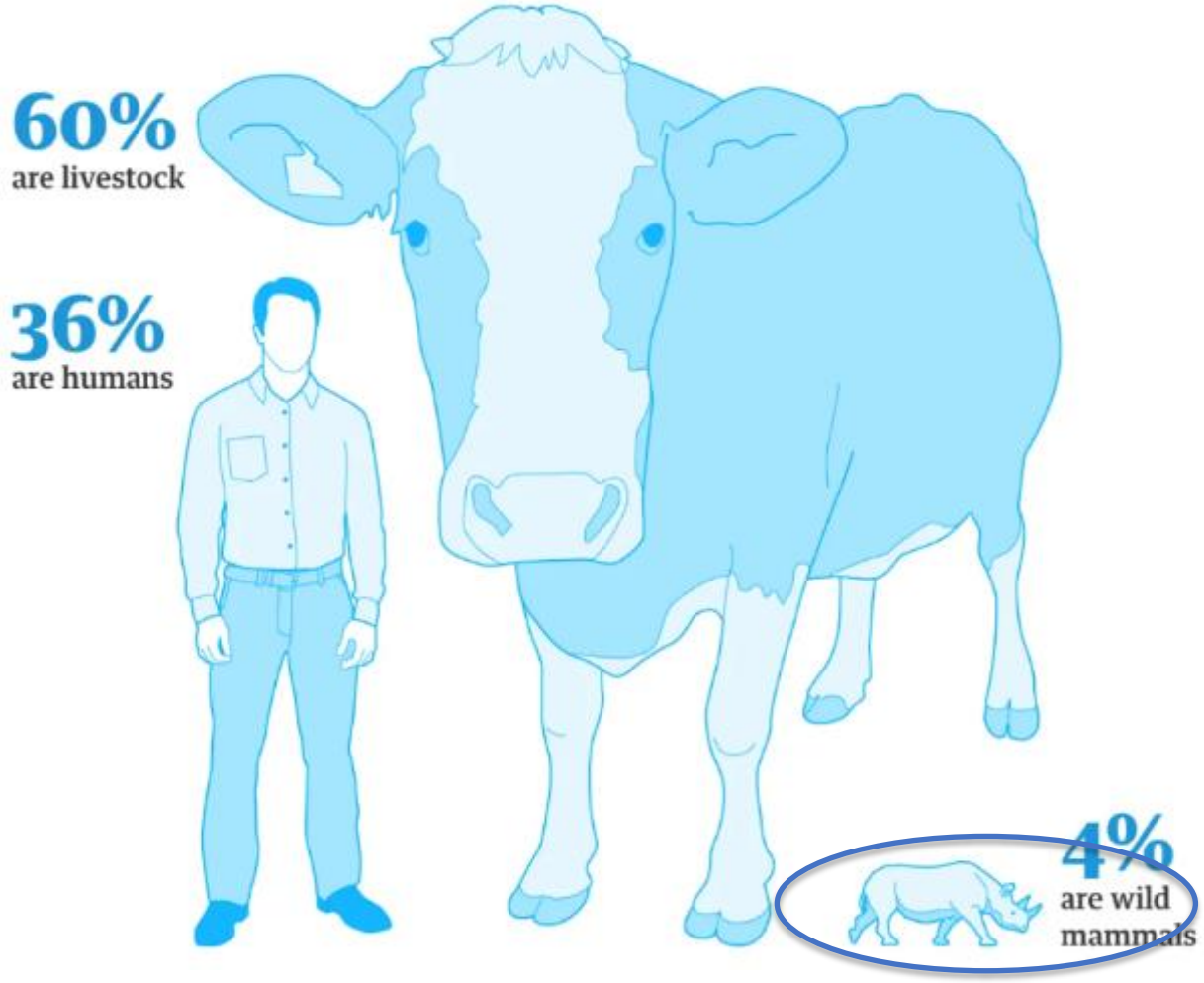


Restoration and rewilding

- Minimum intervention management without predefined density targets

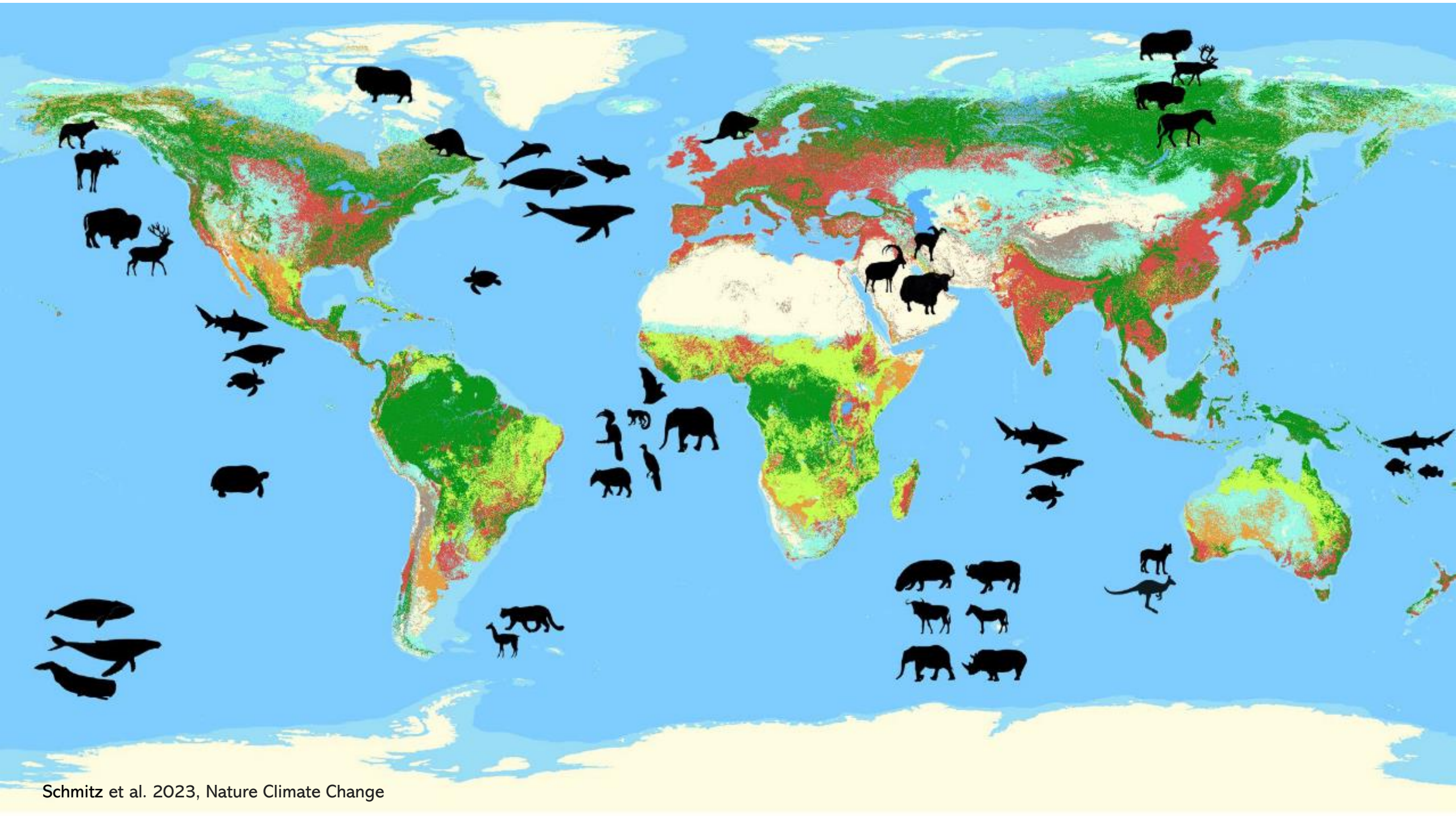
Fløjgaard, C. et al. 2022. JoAppEco.

Biomass of terrestrial mammals on Planet Earth



Are we important for Climate Change M & A?

Bar-Or et al., 2018. PNAS



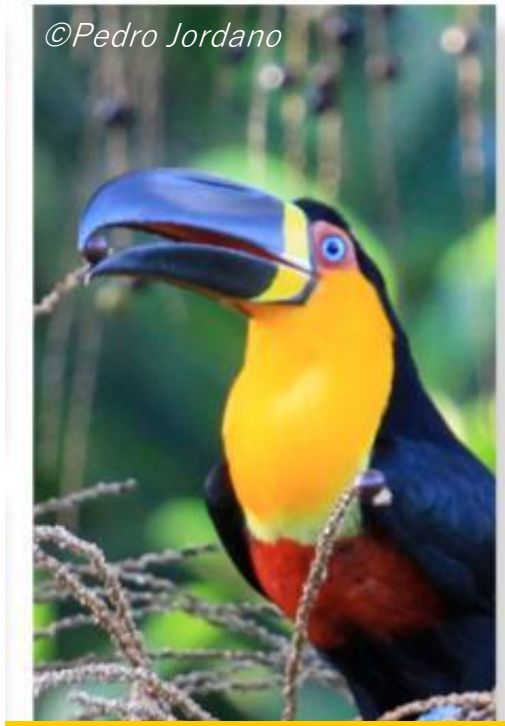
Schmitz et al. 2023, Nature Climate Change

Table 1. Variation between biomes in the influence of large animals.

	Tundra (Figure 3)		Temperate woodland (Figure 3)		Savanna (Figure 3)		Desert, arid systems (Figure 2)		Tropical wet forest (Figure 2)		Temperate grassland (Figure 2)		Boreal forest (Figure 2)		Seagrass (Figure 4)		Tidal marsh		Kelp forest (Figure 4)		Coral reef		Deep sea, open ocean (Figure 4)	
Mitigation (M)/ Adaptation (A)	M	A	M	A	M	A	M	A	M	A	M	A	M	A	M	A	M	A	M	A	M	A	M	A
Vegetation/ autotroph structure and carbon stock above and below-ground	↓	↑	↓	↑	↓	↑	↓	↑	↑	↑	~	↑	↓	↑	↓	~	↓	~	↓	~	~	↑	↑	?
Carbon storage in soil, sediments and deep waters	↑	↑	↑	↑	+/-	+/-	+/-	+/-	↑	↑	↑	↑	↓	↓	+/-	~	↓	~	~	~	~	~	↑	↑
Soil trace gas emissions	↑	~	↑	~	↑	~	+/-	~	+/-	~	↑	~	+/-	~	?	?	↓	~	~	~	~	~	~	~
Animal trace gas emissions	↓	~	↓	~	↓	~	~	~	~	~	↓	~	↓	~	~	~	~	~	~	~	~	~	~	~
Surface albedo	↑	↑	↑	↑	↑	↑	↑	↑	~	~	↑	↑	↑	↑	~	~	~	~	↓	~	~	~	↓	↓
Atmospheric albedo	~	~	~	~	↑	↑	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	?	?
Other biophysical properties	~	↑	~	+/-	~	↓	+/-	+/-	~	~	~	~	~	↑	~	~	~	~	~	~	~	↑	↑	↑
Fire regime	?	?	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	/	/	/	/	/	/	/	/	/	/
Riparian geomorphology and flooding regimes	+/-	↑	+/-	↑	+/-	↑	~	↑	?	?	+/-	↑	+/-	↑	/	/	/	/	/	/	/	/	/	/
Vegetation/ autotroph filtering and dispersal	Climate change adaptation is strongly, positively affected by large animal presence via vegetation/autotroph filtering and dispersal in most biomes. Adaptation effects spill over to mitigation effects by reducing risk of ecosystem breakdown under climate stress																							
Ecosystem complexity (biodiversity,	Climate change adaptation is strongly, positively affected by large animal presence via increased ecosystem complexity in most biomes. Adaptation effects spill over to mitigation effects by reducing risk of ecosystem breakdown under climate stress																							

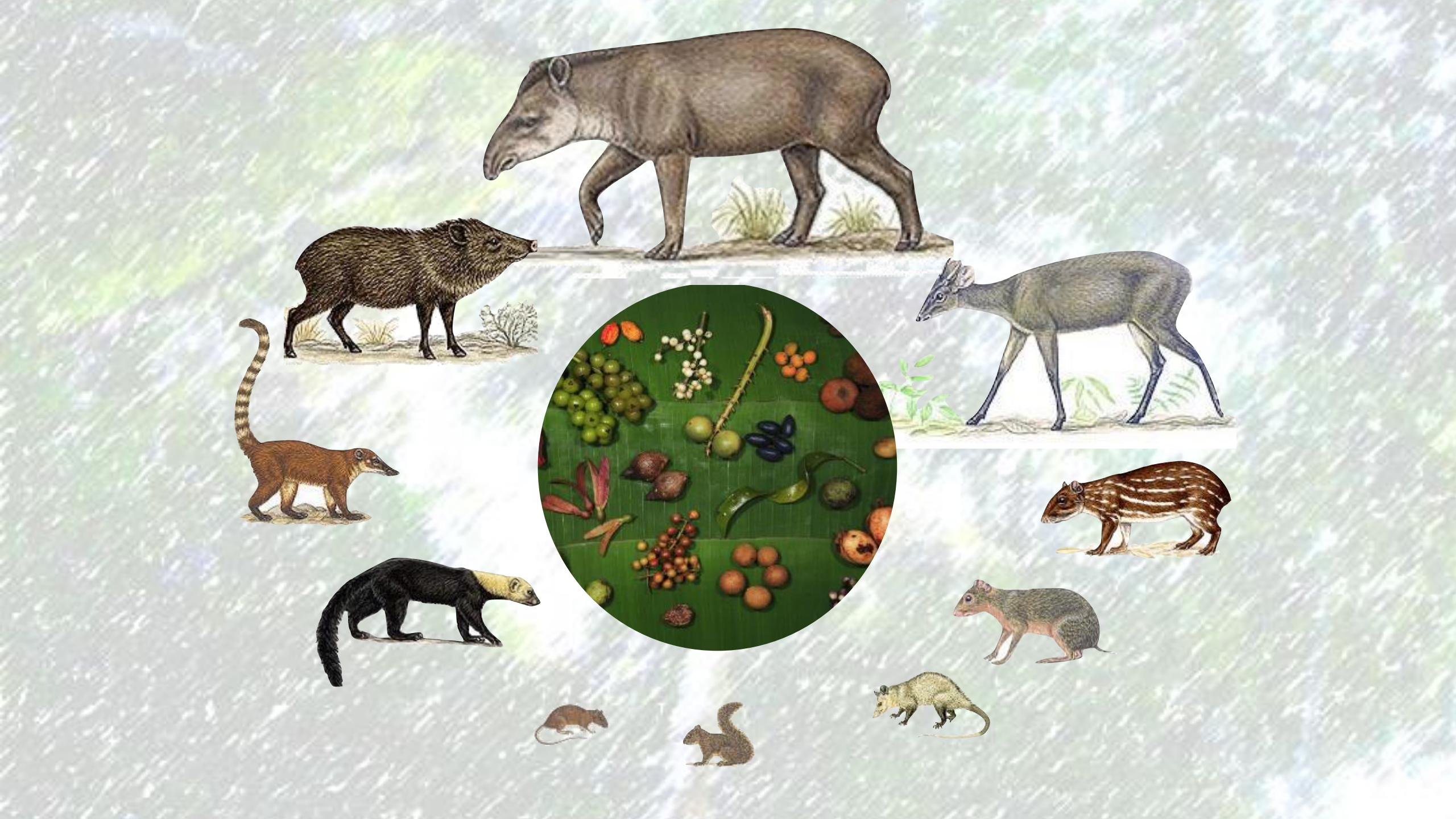
Mahli et al. 2022, Current Biology

Most large animals eat fruits in tropical forests

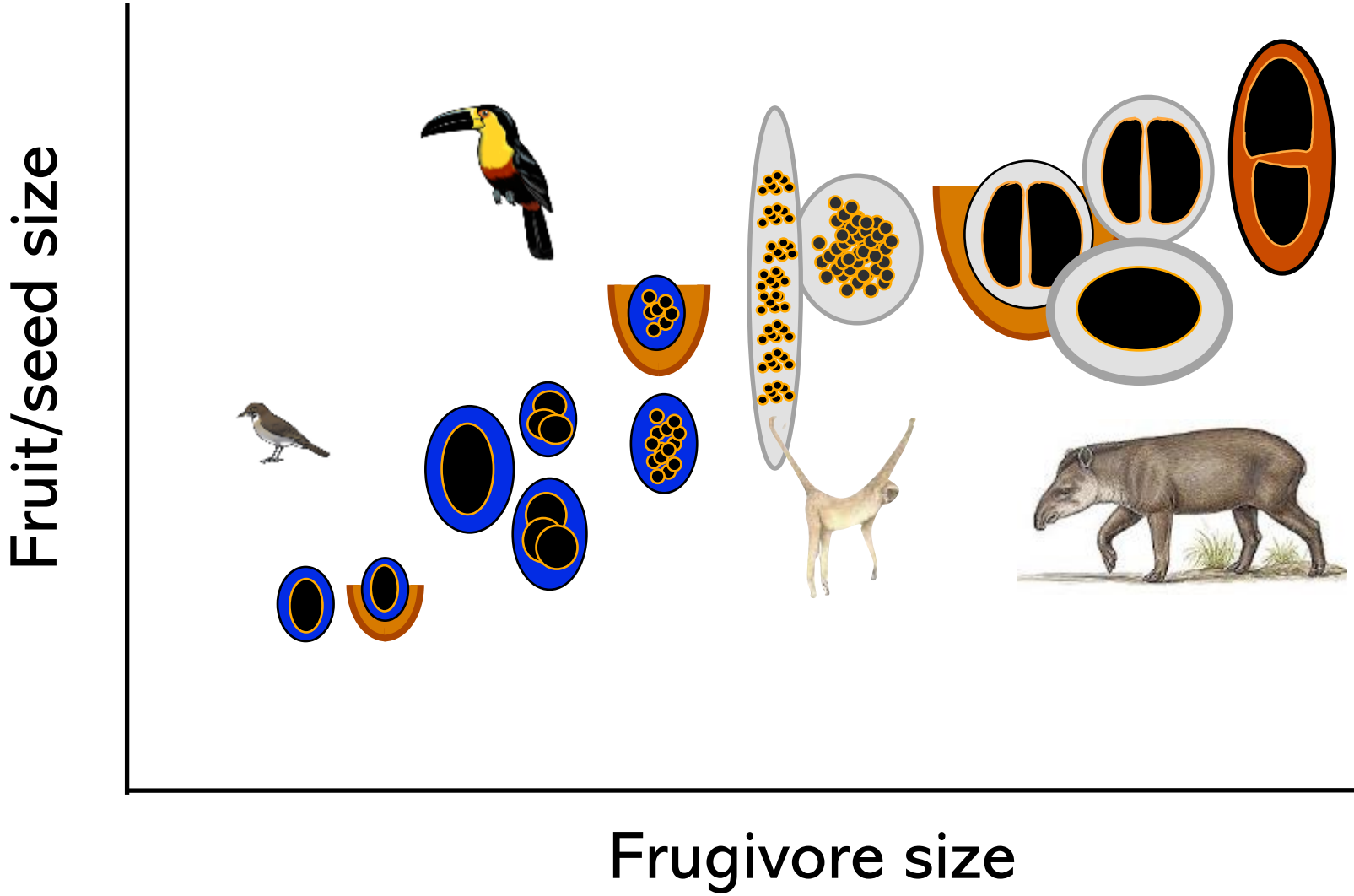


89% woody species animal dispersed

Almeida –Neto et al. 2008; Jordano 2000

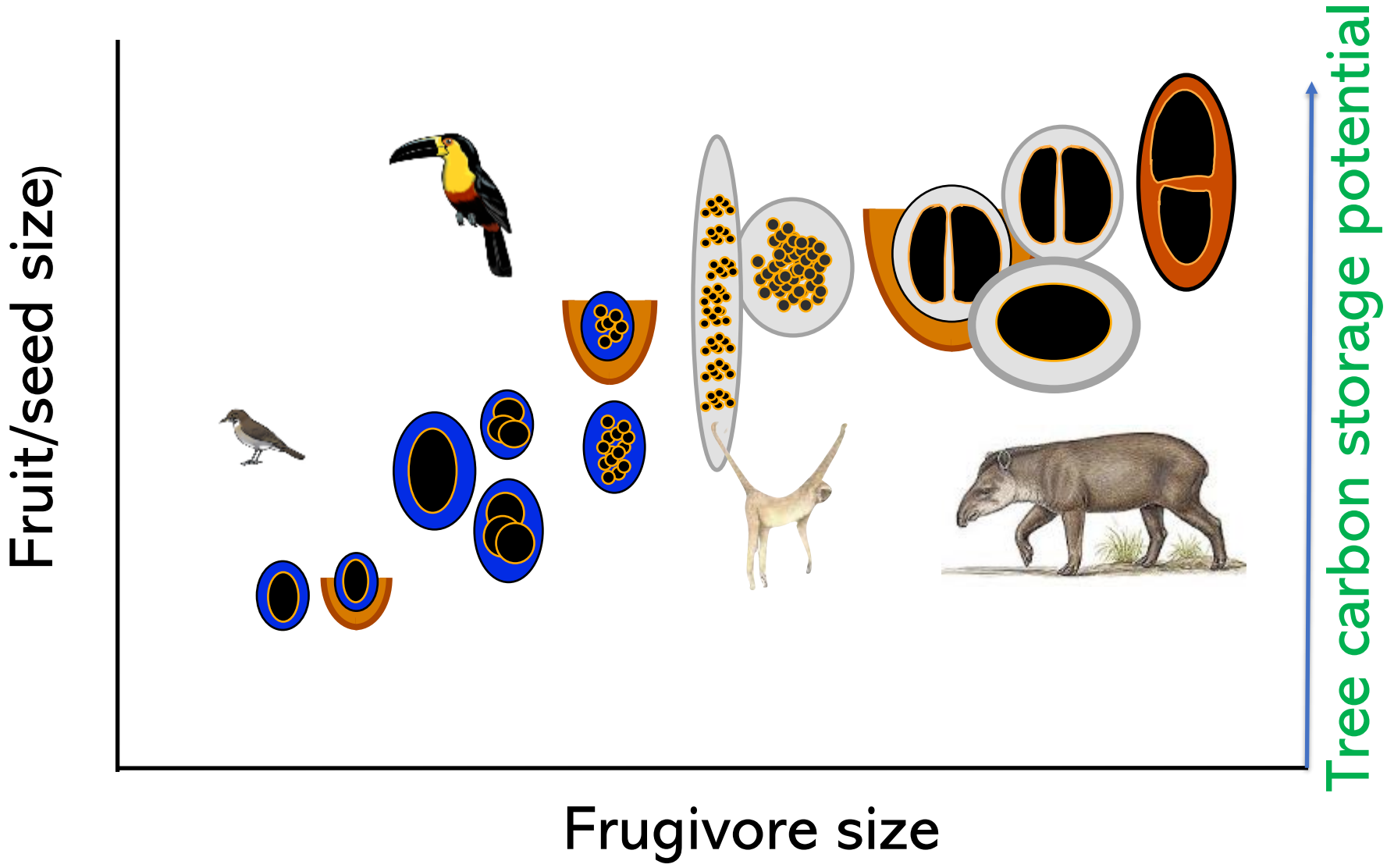


Large frugivores eat and disperse large fruits

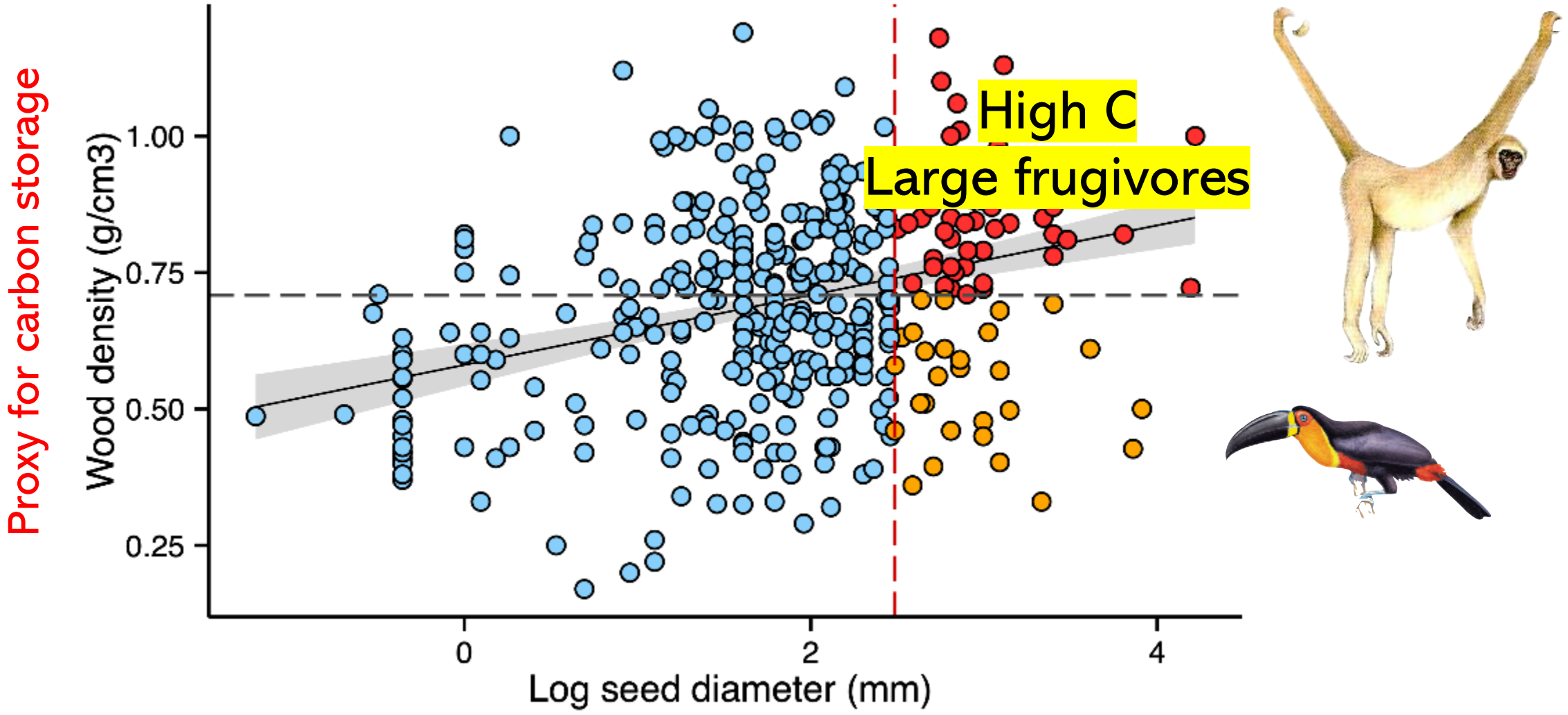


Bello et al. 2014. Ecology

Large fruits come from trees that store more carbon

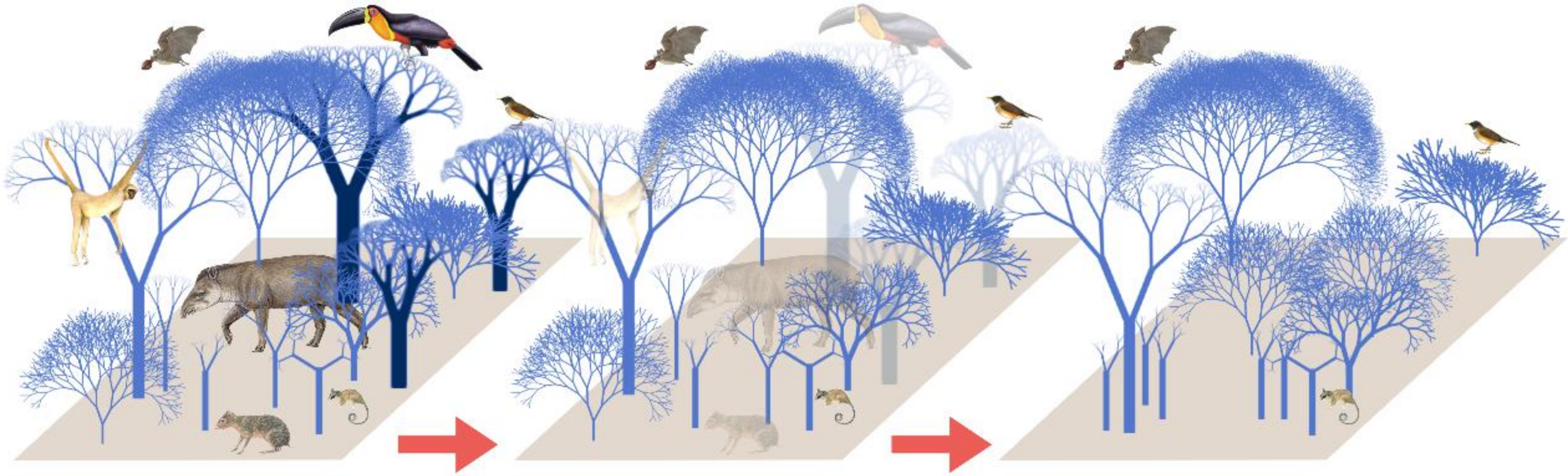


Positive correlation between seed size and wood density



Bello et al. 2015. Science Adv.

Frugivore defaunation leads to loss of high carbon trees



Initial community

High carbon

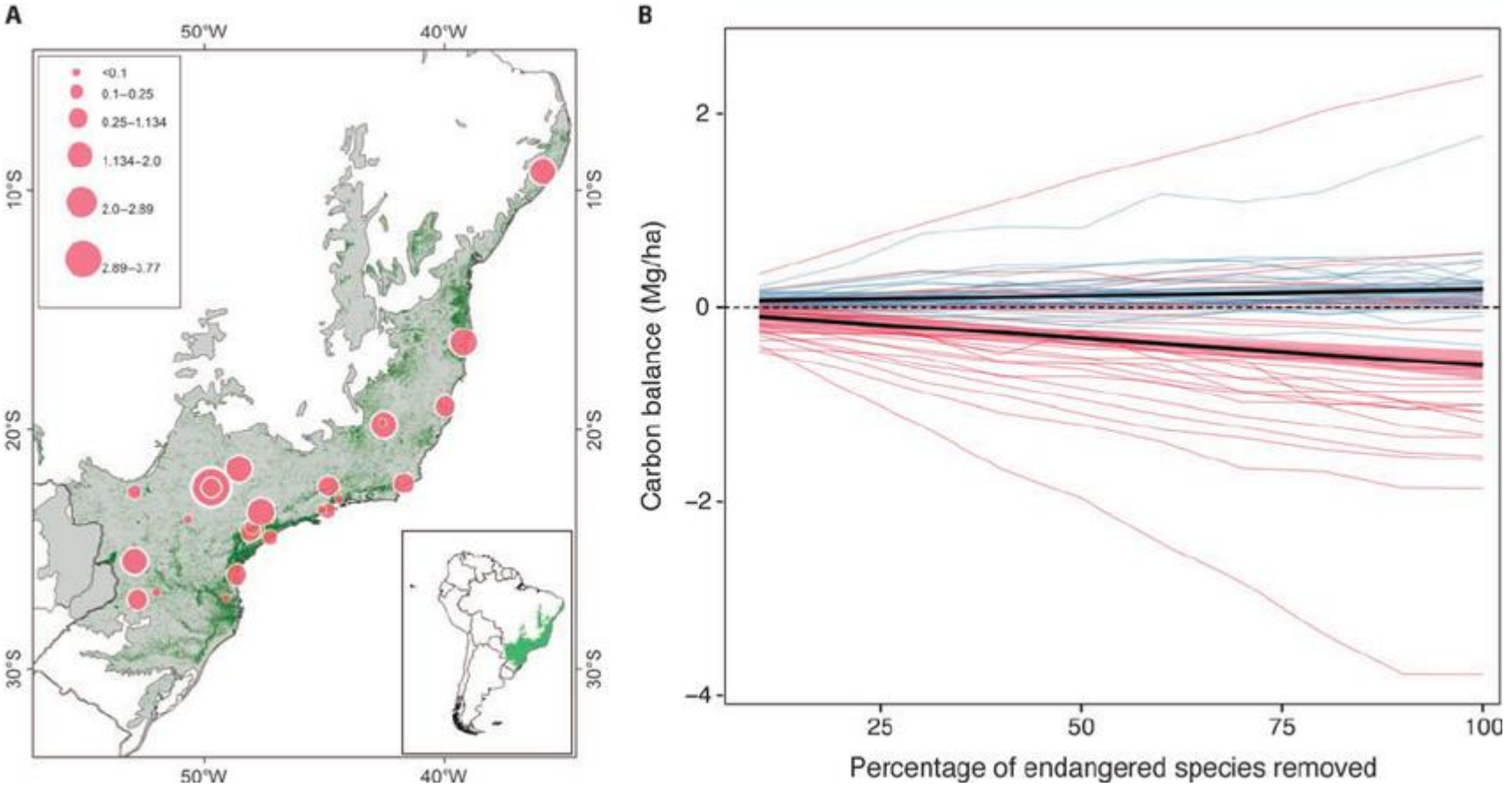
Directed, non-random, extinction of large-bodied frugivores

Final defaunated community

Low carbon

Bello et al. 2015. Science Adv.

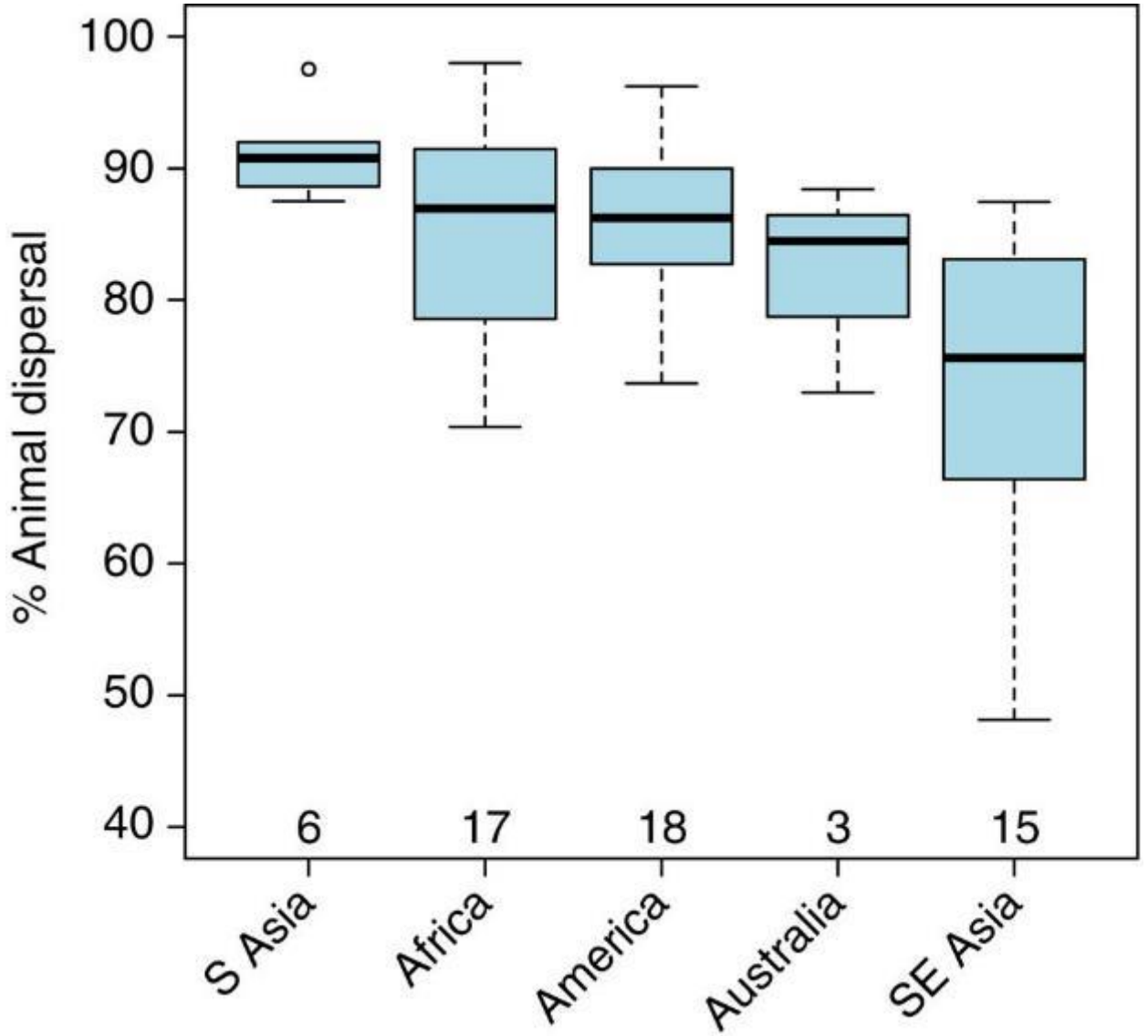
Frugivore defaunation leads to carbon erosion



31 communities
813 tree species (21% large seeds)
101,211 trees

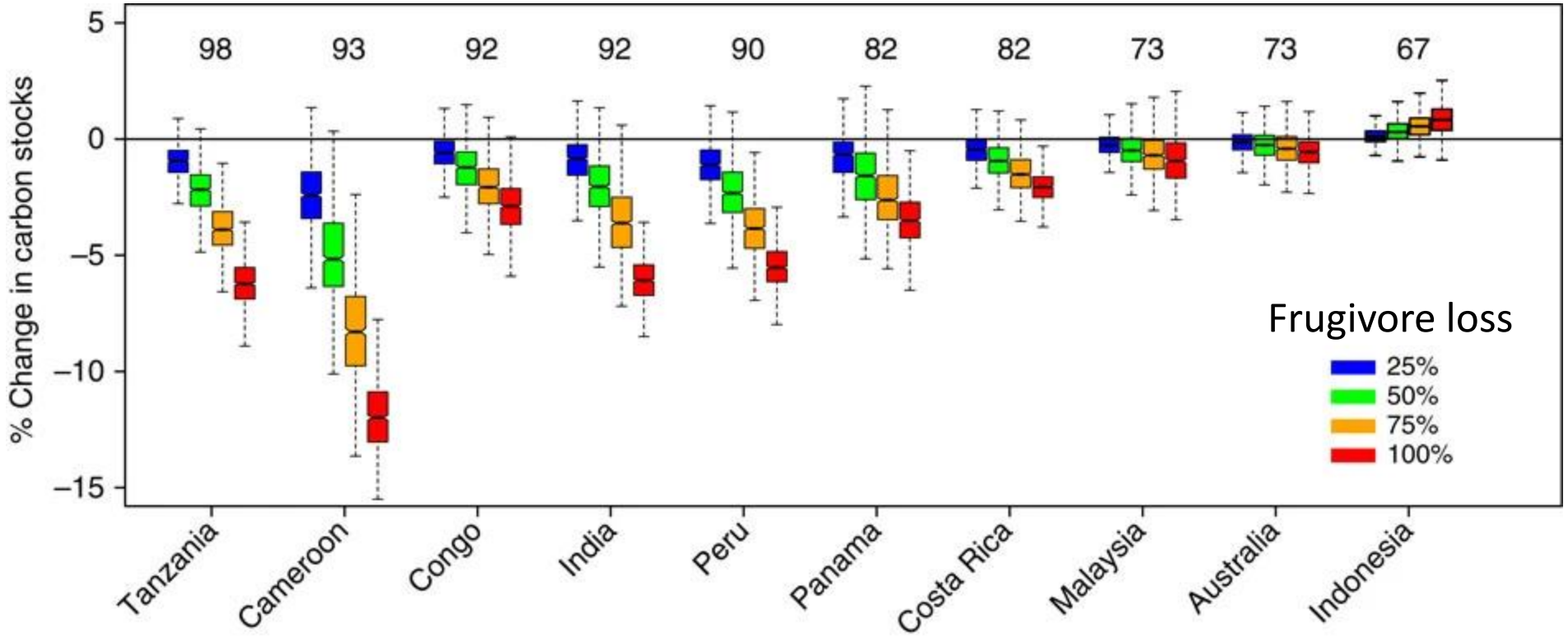
Bello et al. 2015. Science Adv.

% Animal seed dispersal changes across the world



Osuri et al. 2016 Nat Commun.

Frugivore defaunation leads to carbon erosion



Osuri et al. 2016 Nat Commun.

Rewilding frugivory for carbon sequestration

Received: 24 September 2019 | Revised: 4 February 2020 | Accepted: 19 February 2020

DOI: 10.1111/btp.12788

ORIGINAL ARTICLE

bioTROPICA ASSOCIATION FOR TROPICAL BIOLOGY AND CONSERVATION WILEY

Agouti reintroduction recovers seed dispersal of a large-seeded tropical tree

Pedro Mittelman[1] | Catharina Kreischer[1] | Alexandra S. Pires[2] | Fernando A. S. Fernandez[1]

Dispersal of large seeded trees

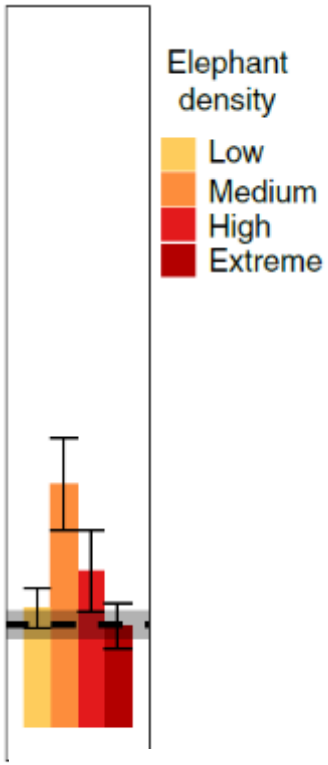
Feeding on tasty leaves from low carbon trees = promoting high carbon survivors

Trampling on “weak” young low carbon trees = promoting high carbon survivors

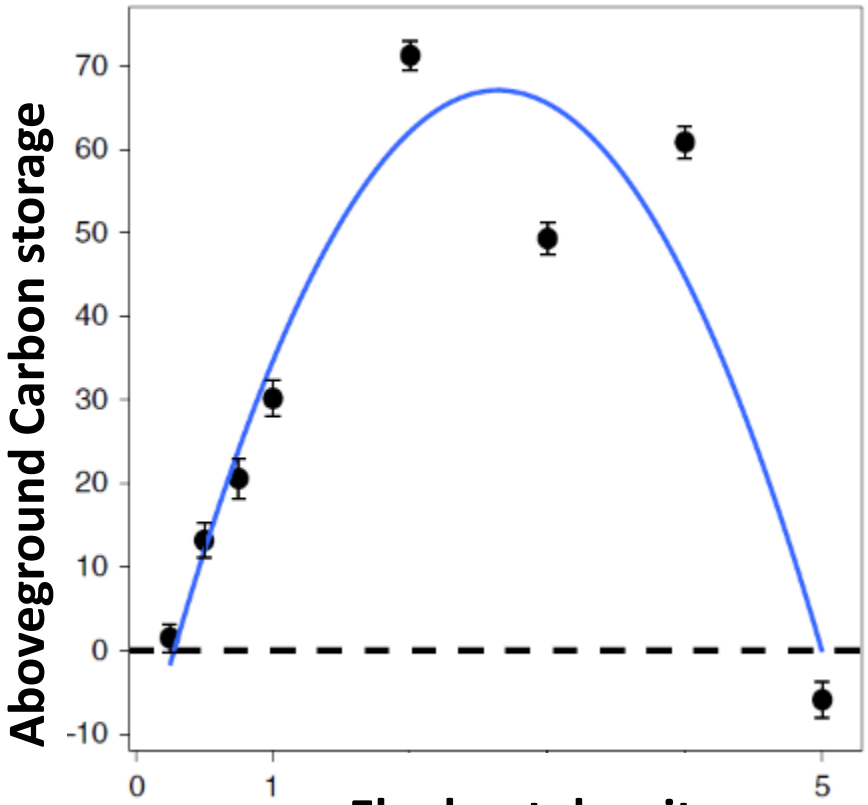
Forest elephants also increase carbon at intermediate densities through multiple pathways

Berzaghi et al. 2019, Nat. Geosci.;
Berzaghi et al. 2023, PNAS

Forest elephants are carbon storing machines



Large trees



Berzaghi et al. 2019, Nat. Geosci.

How much is one forest elephant worth?

The carbon value of a single forest elephant is $1.75 million

Major threats

Poaching
Centuries are required for forest elephants to recover to their historic population level of **1.1 million**, from their current population of **100,000**

Elephant Forestry Increase
Each forest elephant can stimulate a net increase in carbon capture in central African rainforests of **9,000 metric tons** of carbon dioxide per km²

Elephant Biomass Carbon
The amount of carbon on each elephant is equivalent to **2.64 metric tons** of carbon dioxide

Major threats

Deforestation
Deforestation in Africa is happening **4x** faster than the global rate, resulting in an average loss roughly of **40,000** square kilometers per year

Source: African Wildlife Foundation 2015

GRID-Arendal 2020

Savannah elephants steal aboveground carbon

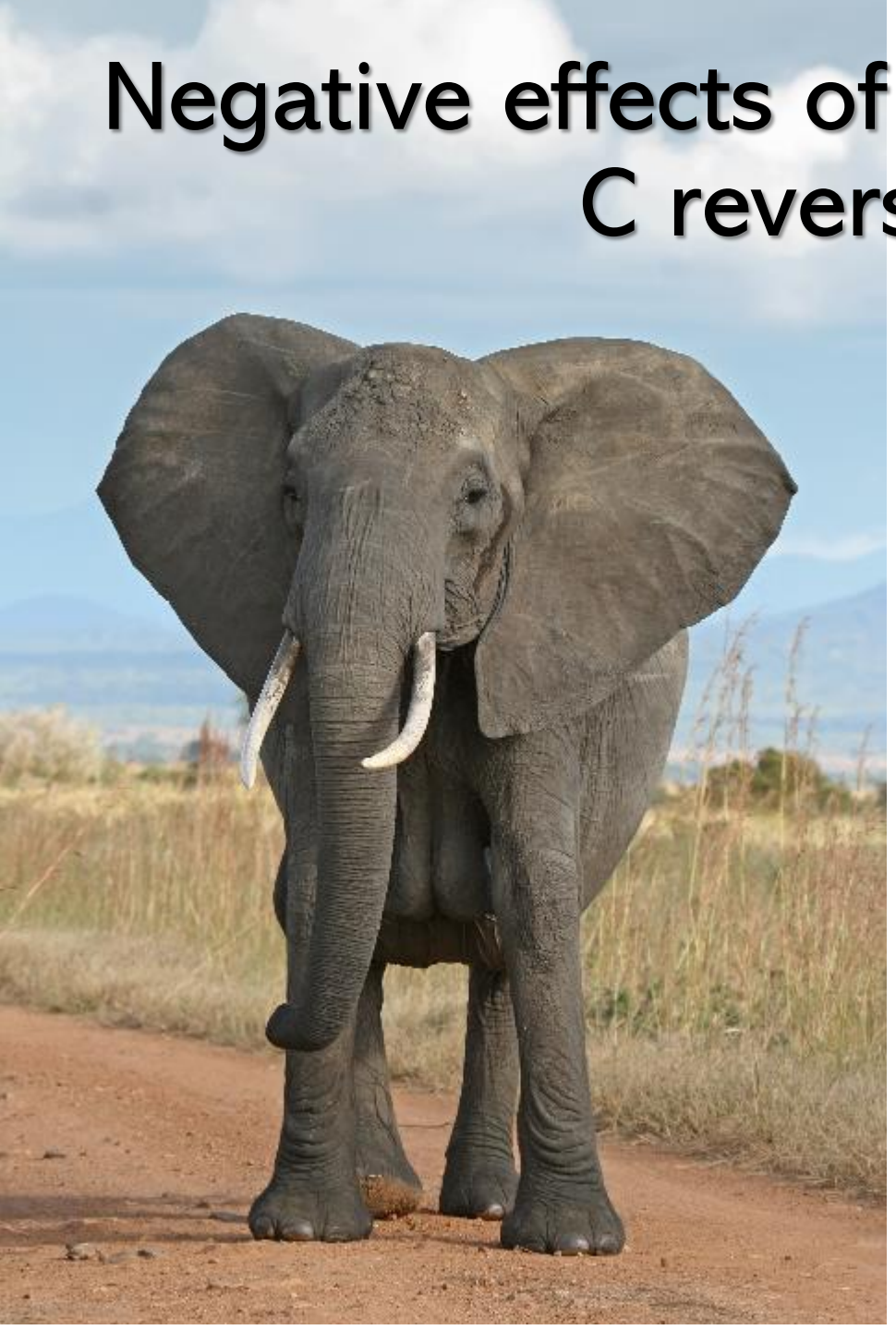
Davies et al. 2019 Glob Change Biol.

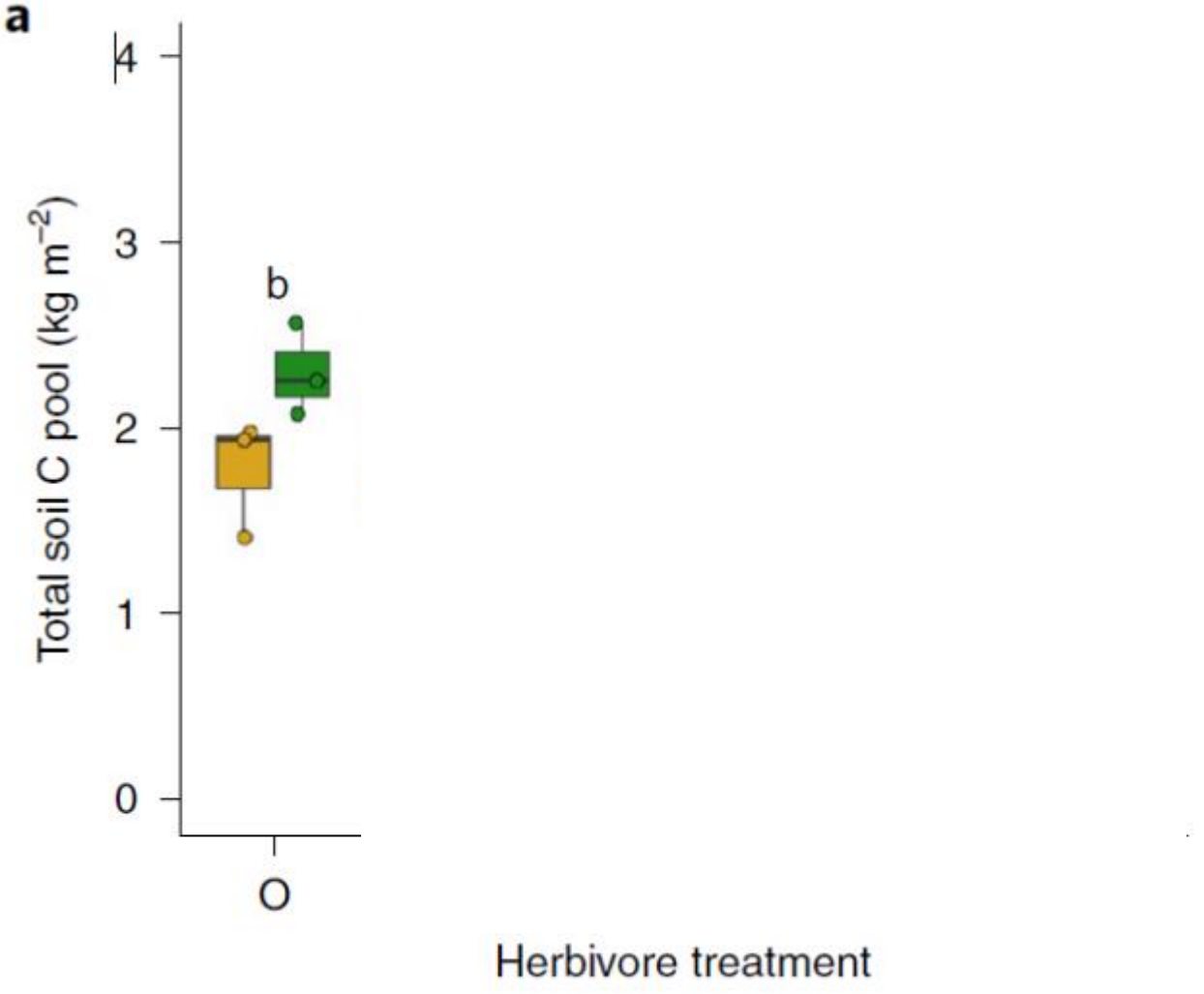
Credits: JONATHAN & ANGELA SCOTT/AWL IMAGES

.....and store it belowground

Sitters et al. 2020, Nat Sustain

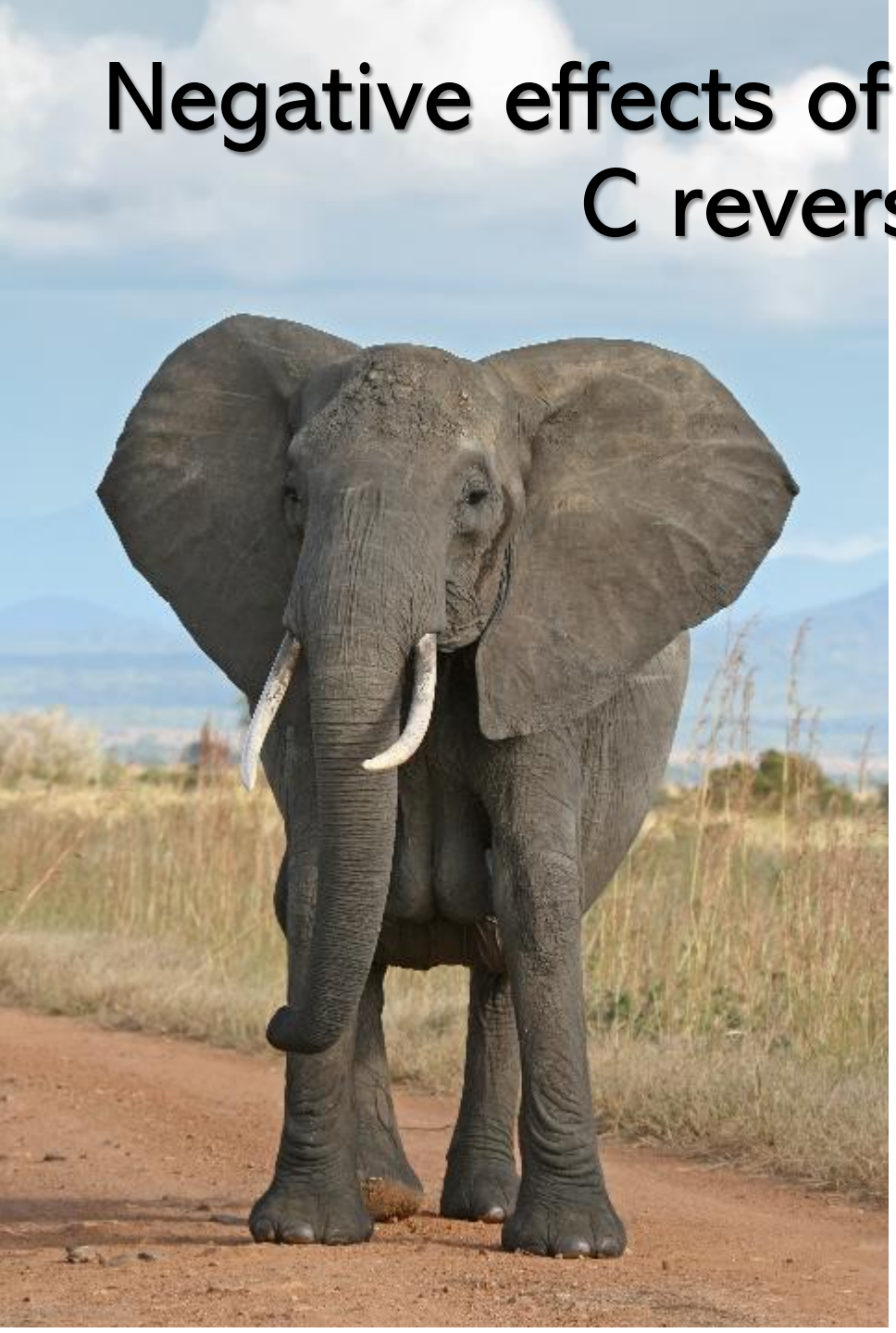
Negative effects of cattle and mesoherbivores on soil C reversed by Megaherbivores

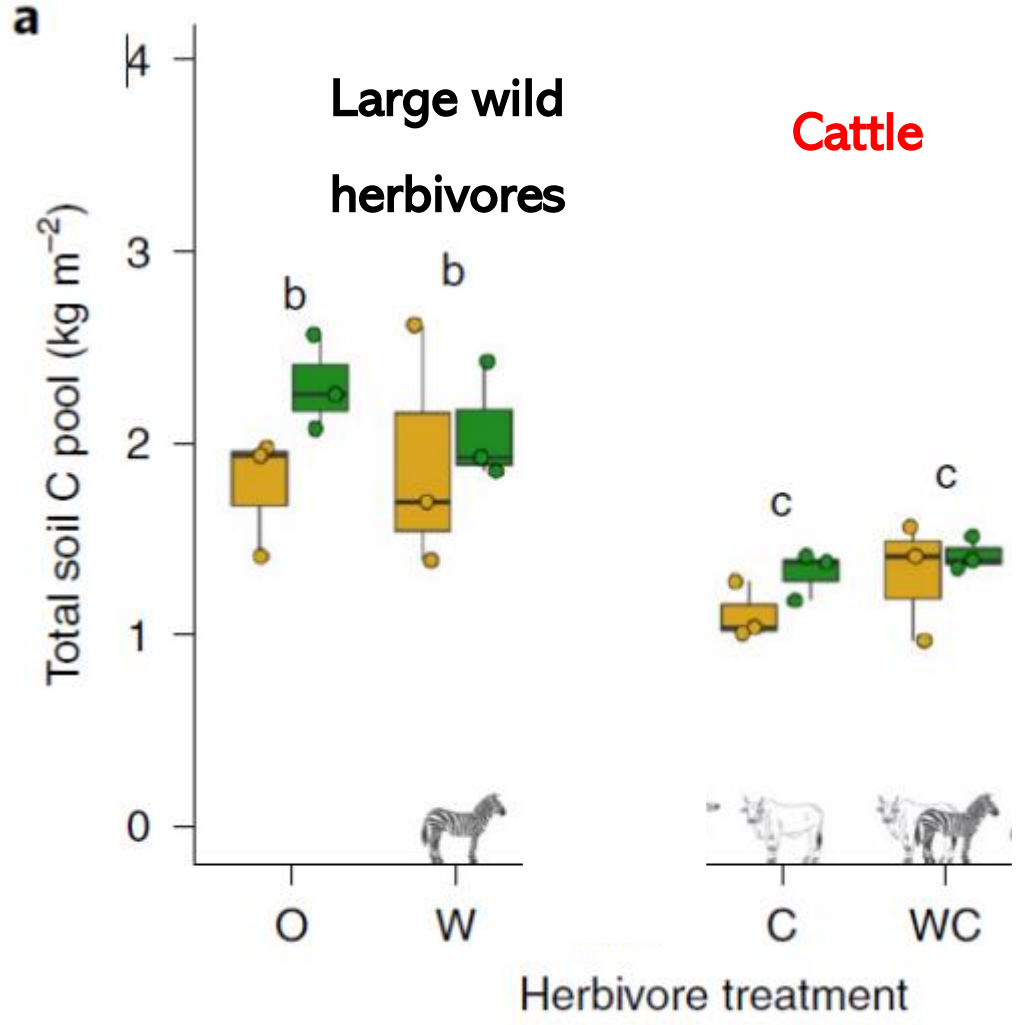




Sitters et al. 2020, Nat Sustain

Negative effects of cattle and mesoherbivores on soil C reversed by Megaherbivores





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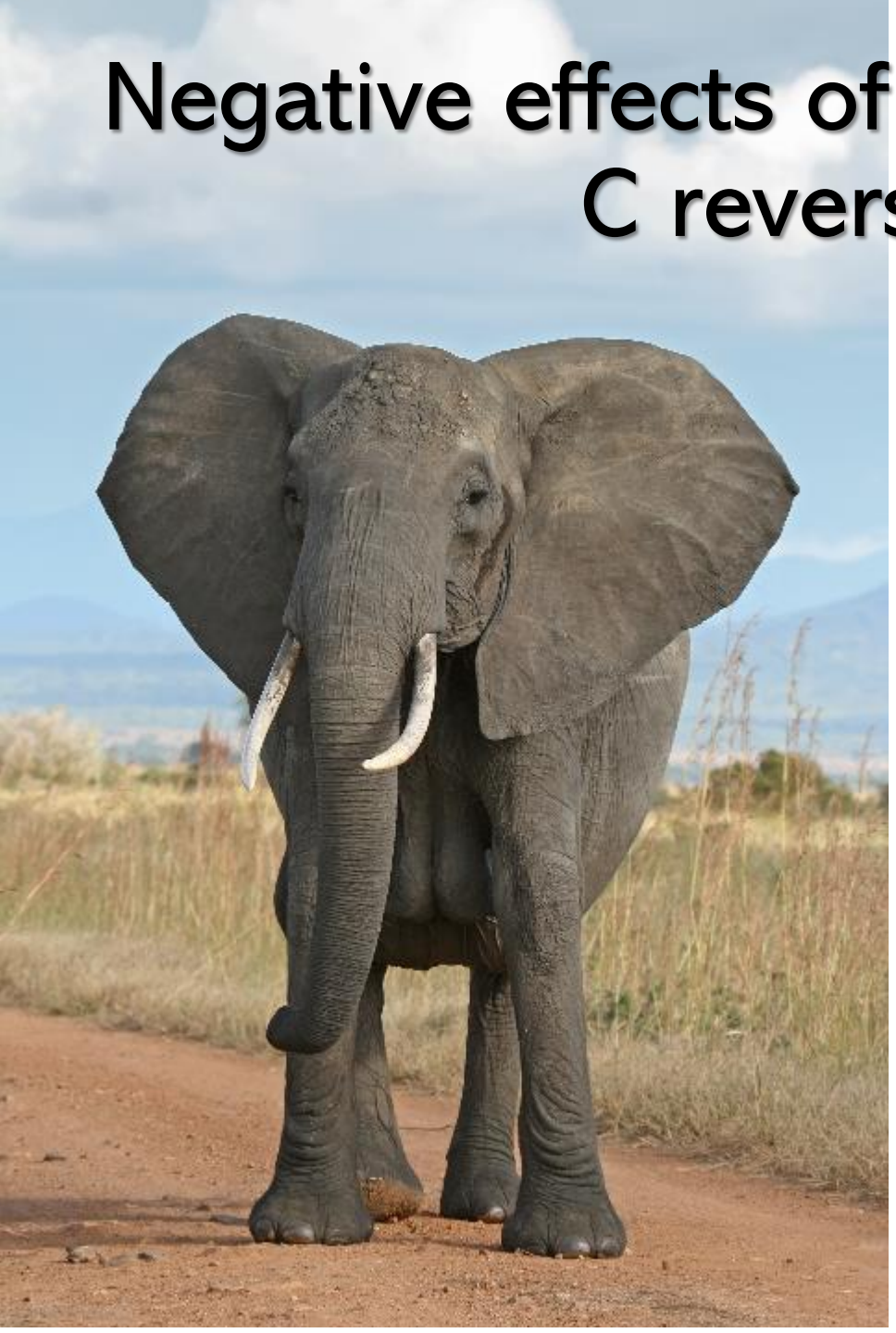
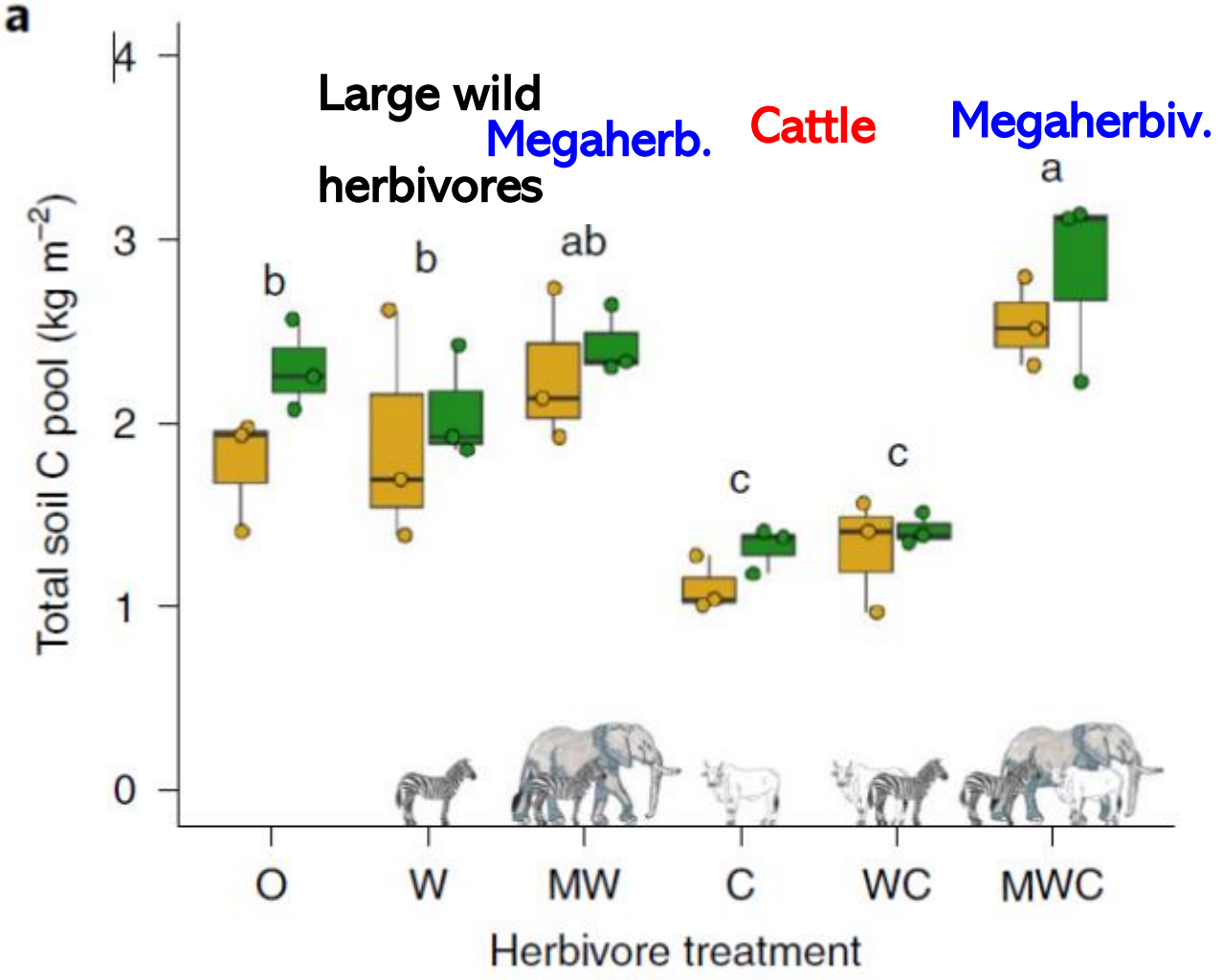
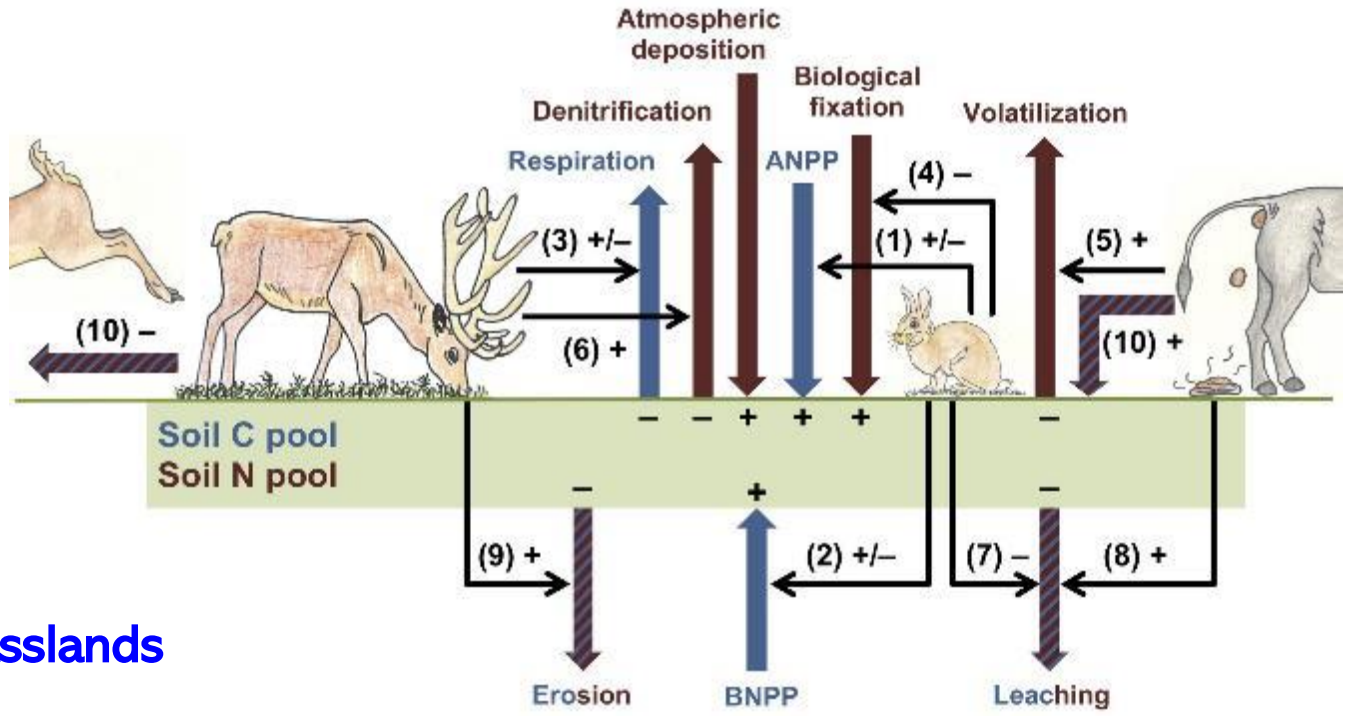
Negative effects of cattle and mesoherbivores on soil C reversed by Megaherbivores





Sitters et al. 2020, Nat Sustain

Grasslands: effects of large herbivores on soil C changes with environmental conditions



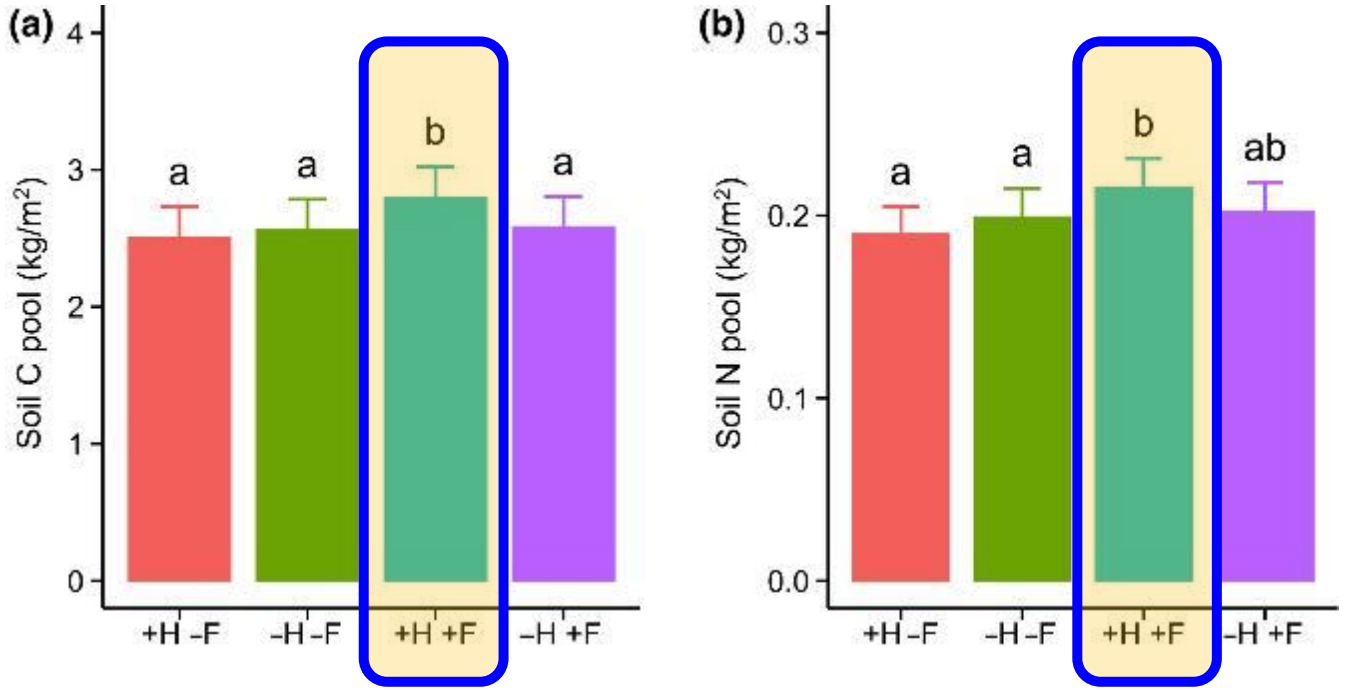
Warm grasslands

Cold grasslands

Soil Carbon & Nitrogen

Sitters et al. 2020, Glob. Change Biol

Herbivores increase soil C and N where there is nutrient enrichment



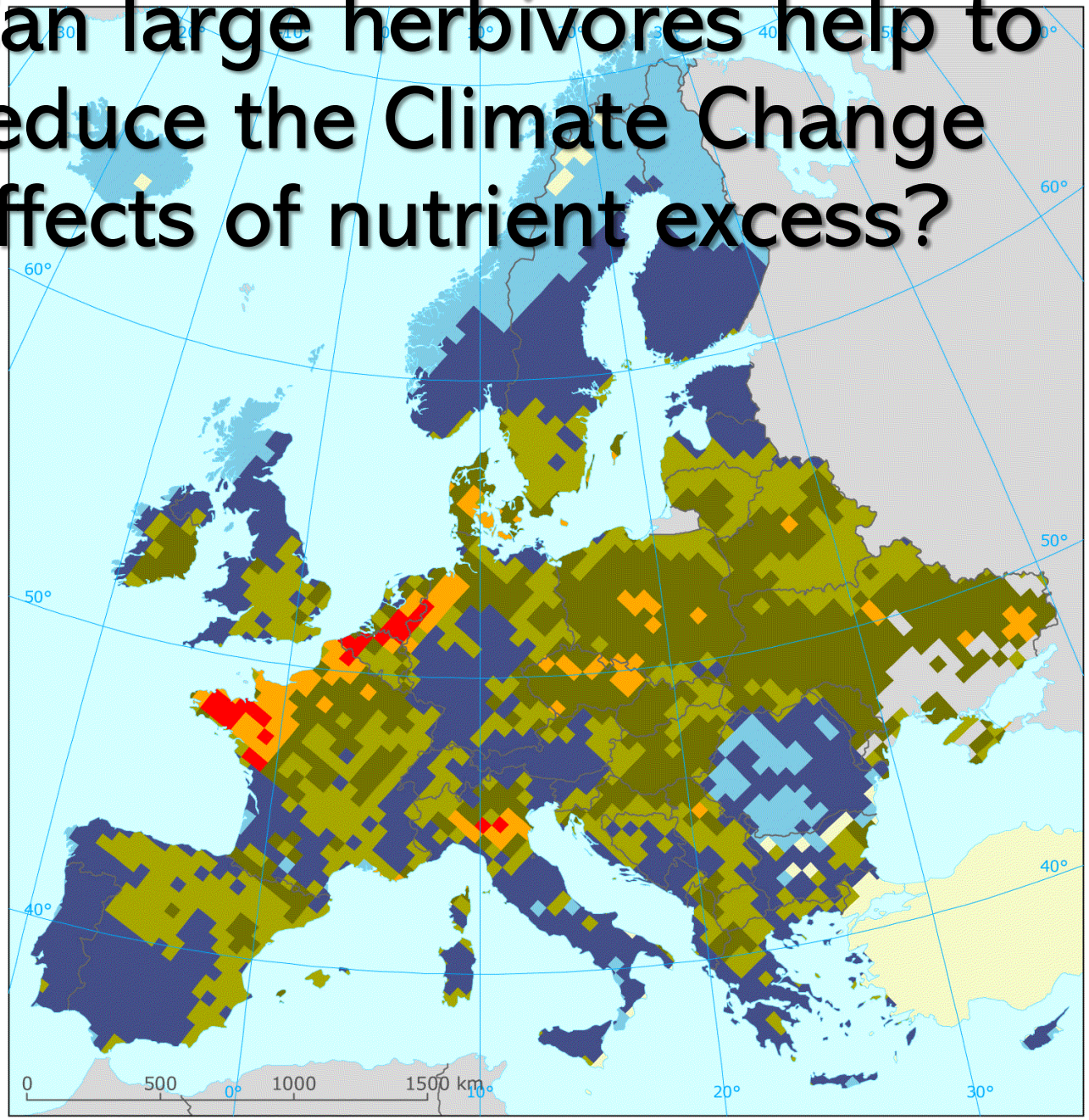
Sitters et al. 2020, Glob. Change Biol

Herbivores increase soil C and N where there is nutrient enrichment

Herbivores seem to sequester more N in the soil in nutrient enriched sites with higher temperature variability

Sitters et al. 2020, Glob. Change Biol

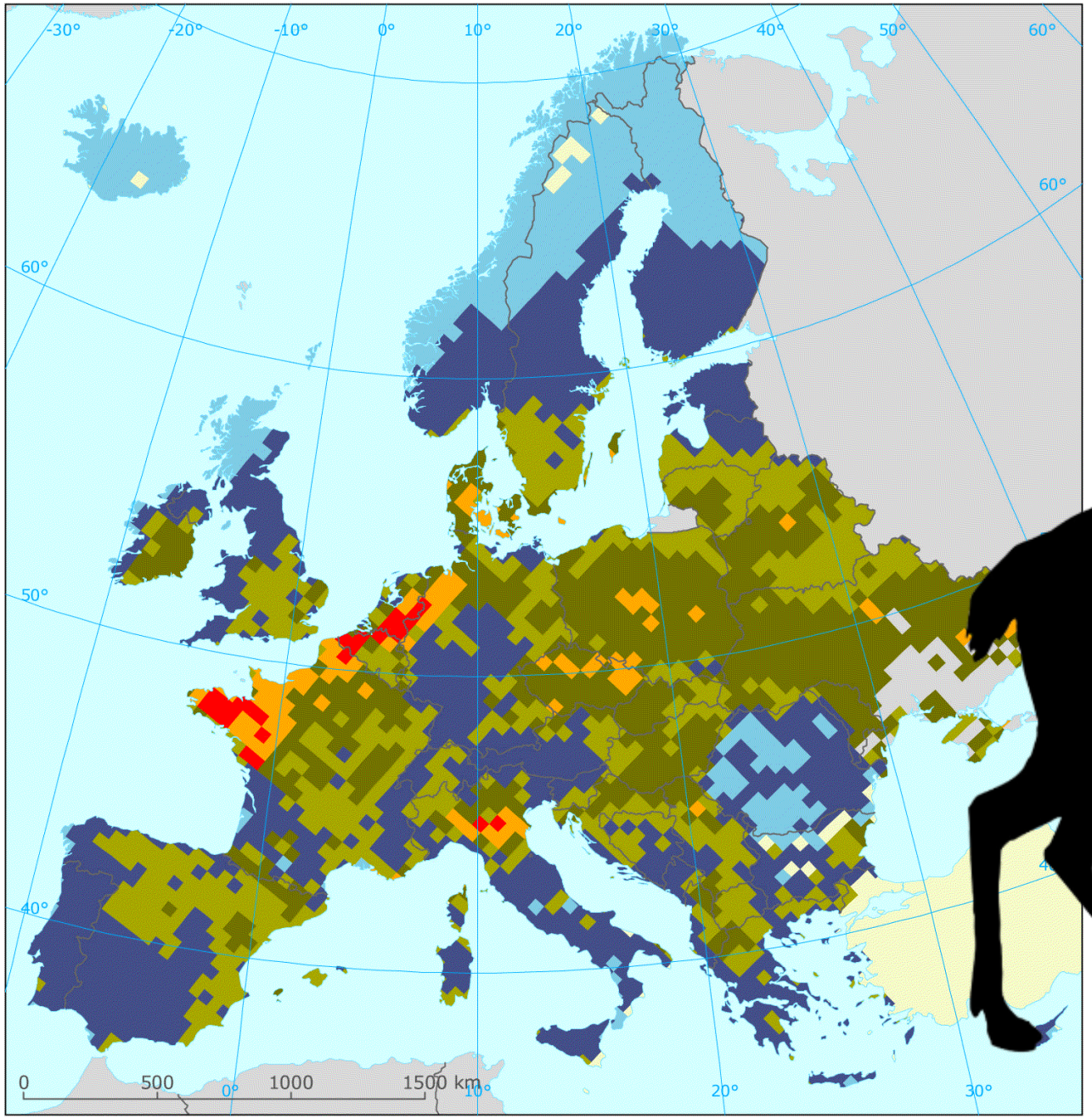
Can large herbivores help to reduce the Climate Change effects of nutrient excess?



Exceedance of nutrient critical loads, 2020 current legislation

eq $ha^{-1}a^{-1}$

- No exceedance
- > 0 – 200
- 200 – 400
- 400 – 700
- 700 – 1 200
- > 1 200

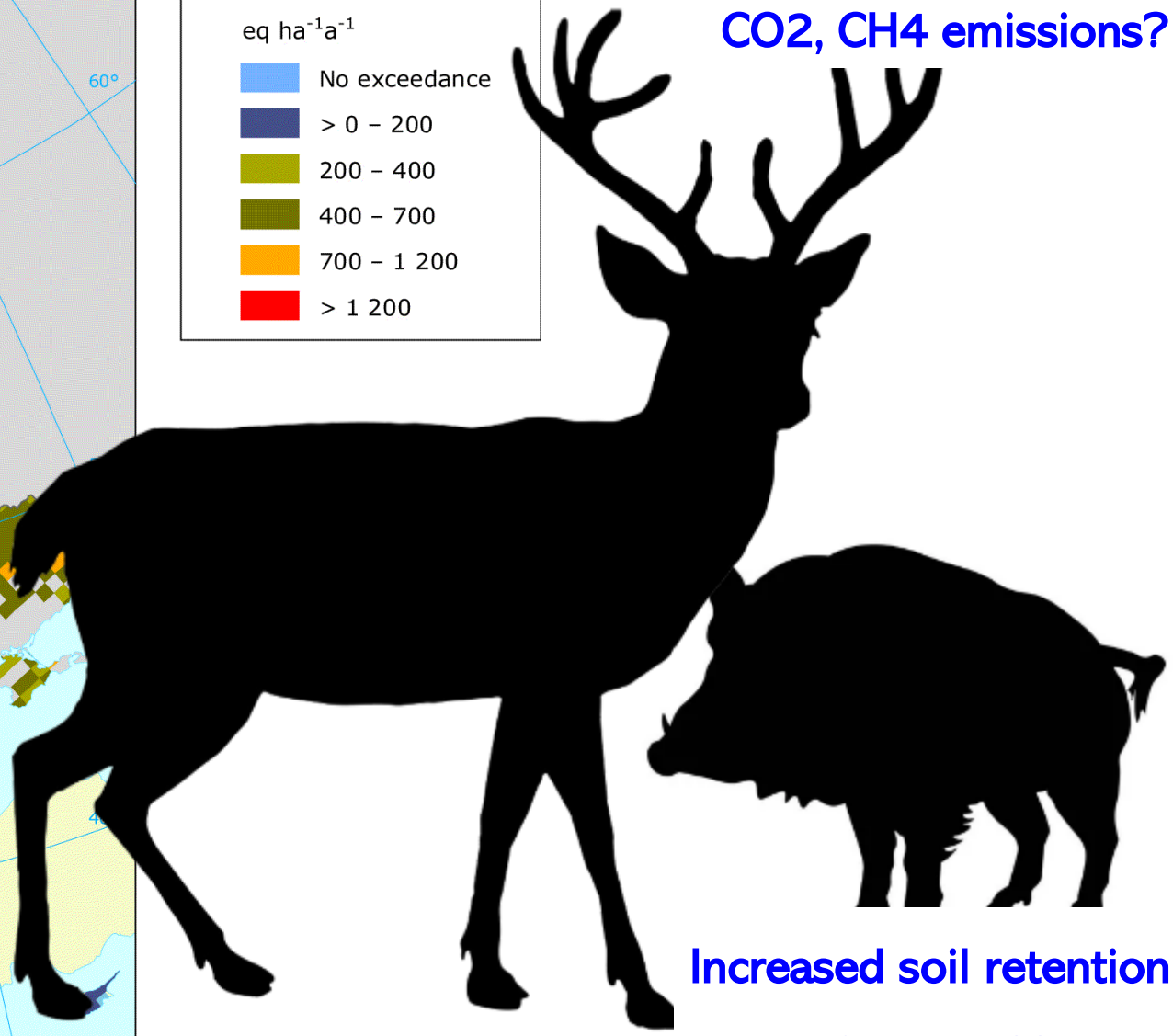


Exceedance of nutrient critical loads, 2020 current legislation

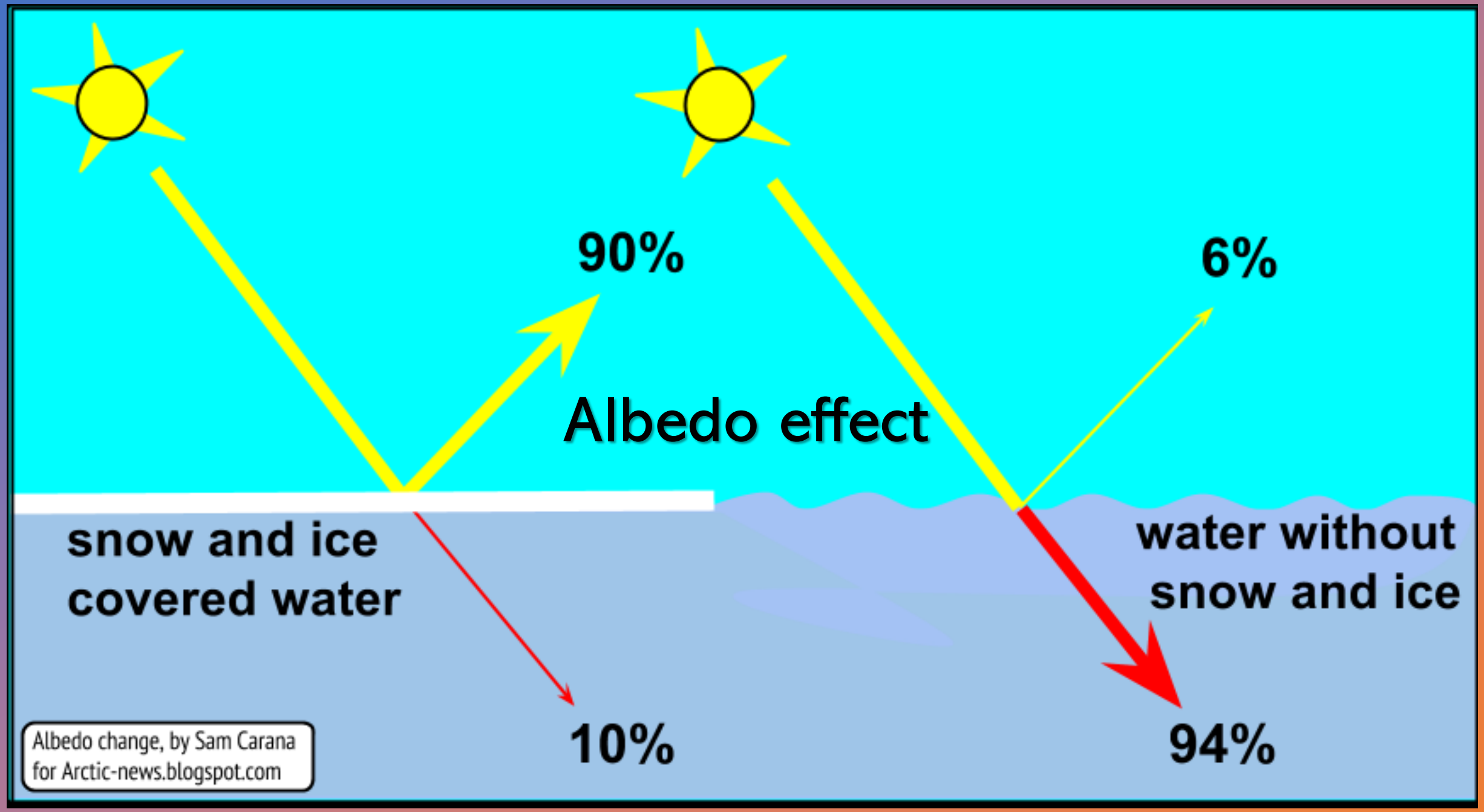
eq $ha^{-1}a^{-1}$

- No exceedance
- > 0 – 200
- 200 – 400
- 400 – 700
- 700 – 1 200
- > 1 200

Reduced soil Greenhouse N2O, CO2, CH4 emissions?

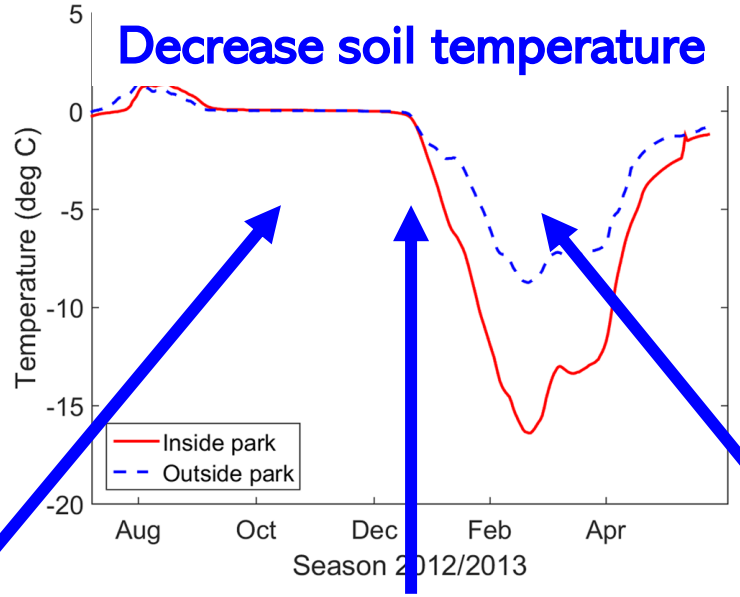


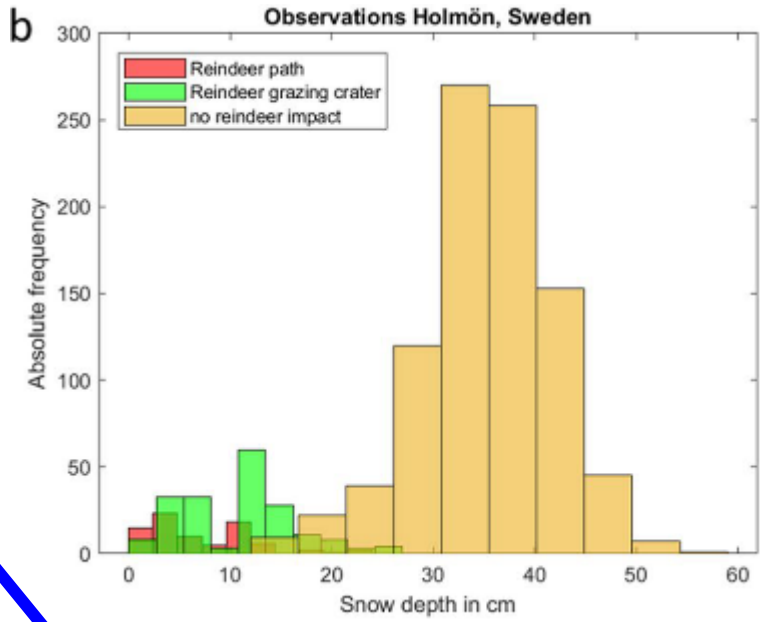
Increased soil retention of N and C?


90%
6%
Albedo effect
snow and ice
covered water
water without
snow and ice
10%
94%
Albedo change, by Sam Carana
for Arctic-news.blogspot.com


How large wildlife affect albedo?

The good news

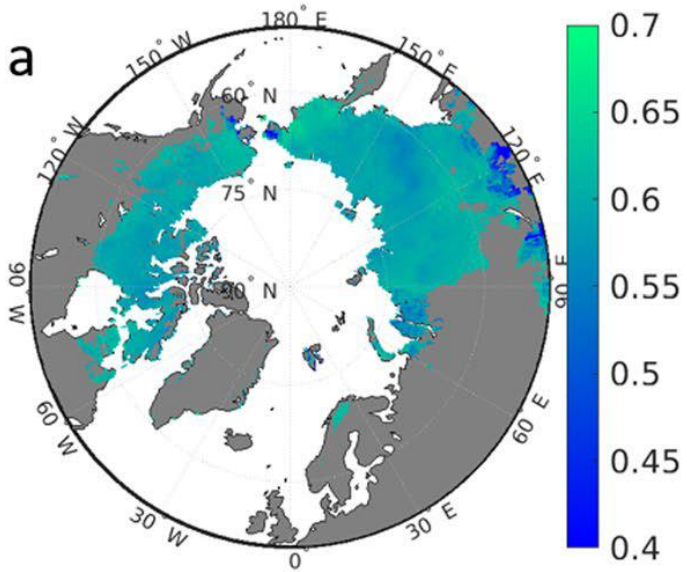


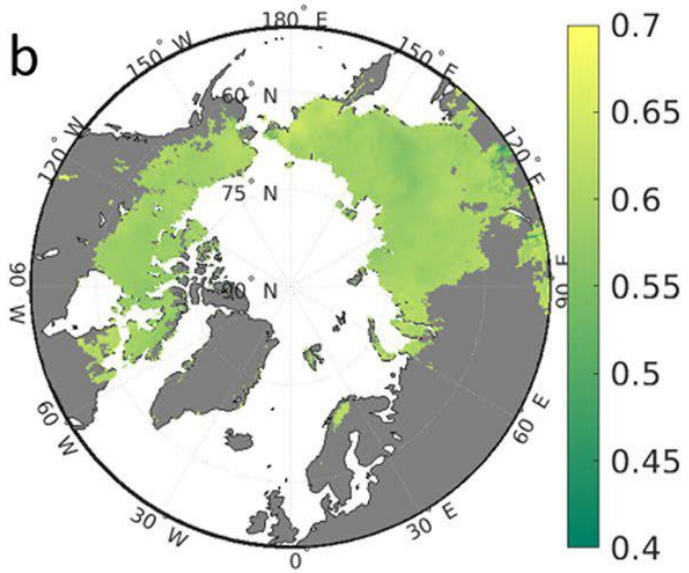


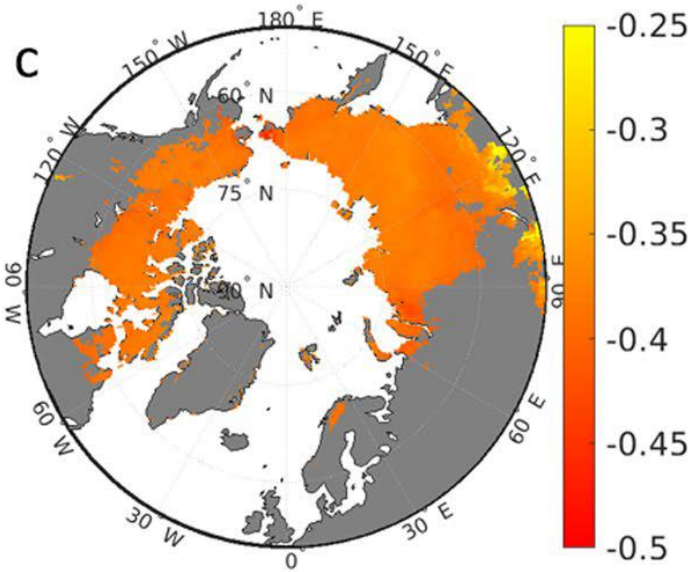
Increase snow density

Increase thermal diffusivity

Decrease on snow depth

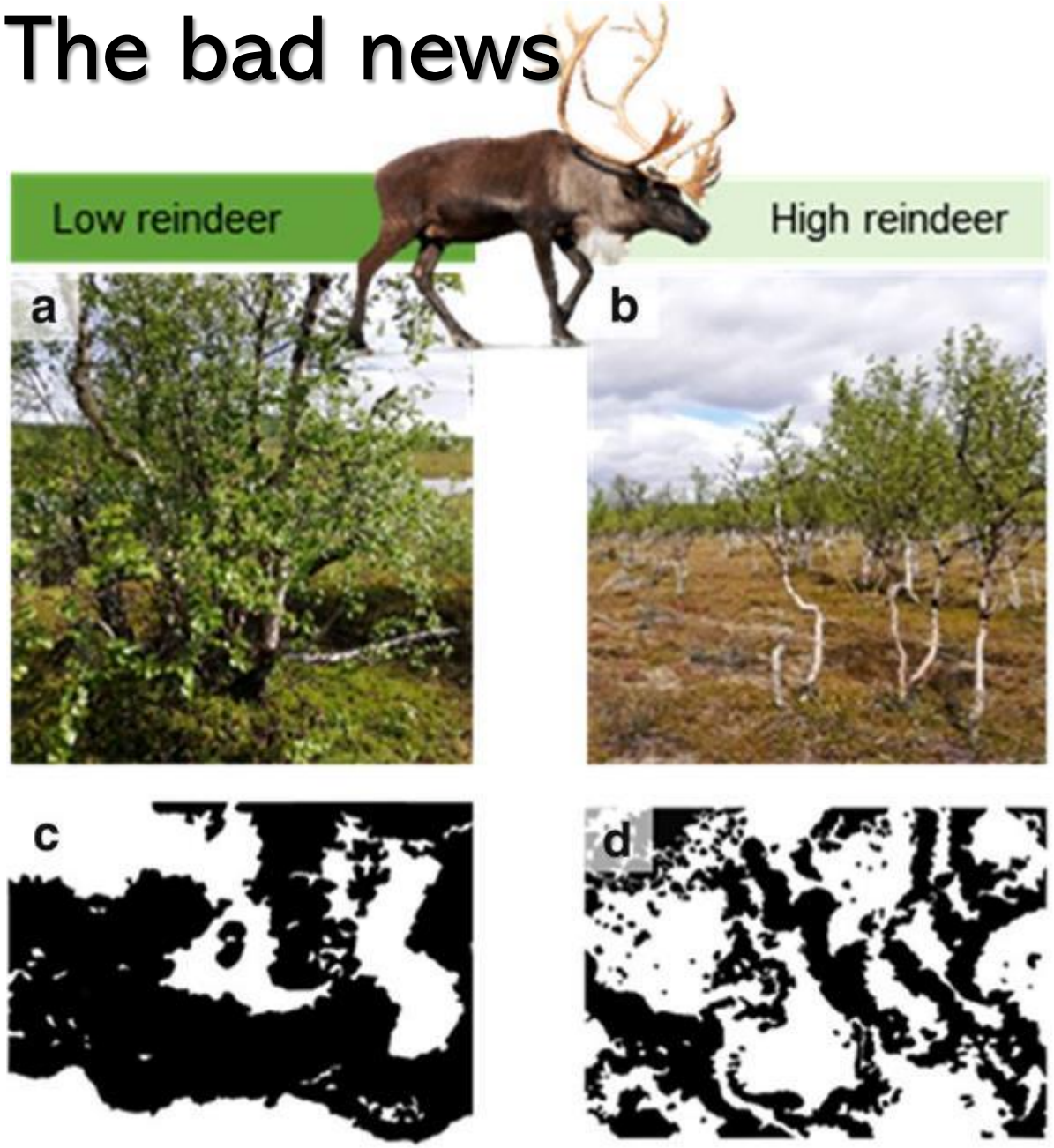


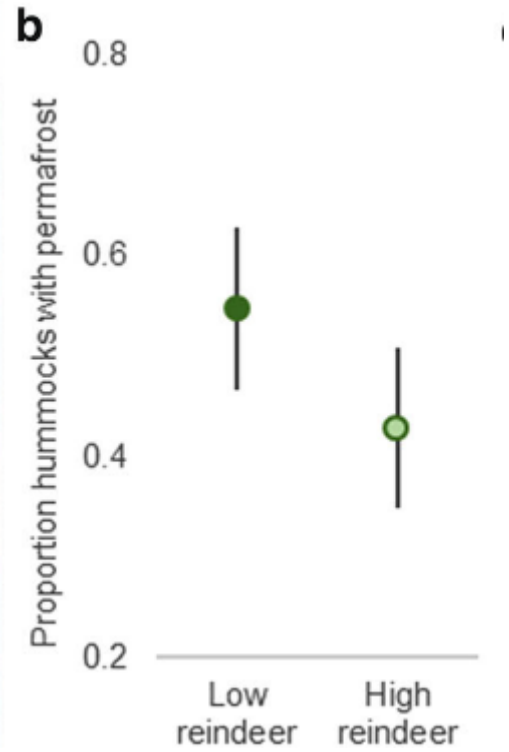


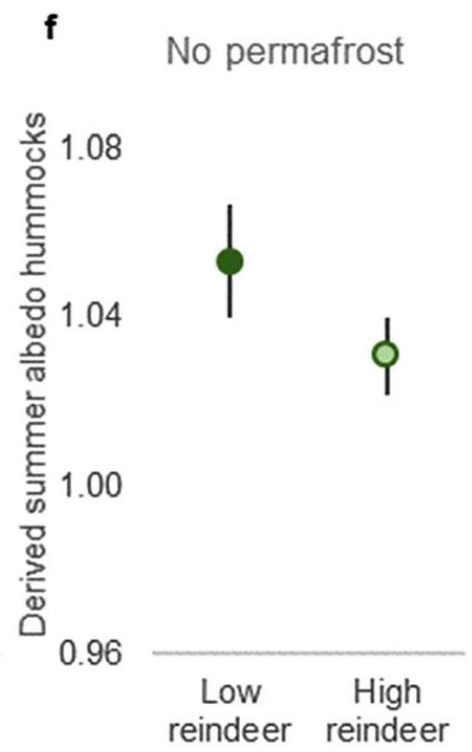


Beer, C., Zimov, N., Olofsson, J. *et al.* Protection of Permafrost Soils from Thawing by Increasing Herbivore Density. *Sci Rep* **10**, 4170 (2020). https://doi.org/10.1038/s41598-020-60938-y

The bad news







Holmgren, M., Groten, F., Carracedo, M.R. *et al.* Rewilding Risks for Peatland Permafrost. *Ecosystems* (2023). https://doi.org/10.1007/s10021-023-00865-x

Trophic cascades: Predators in rescue of Carbon sequestration

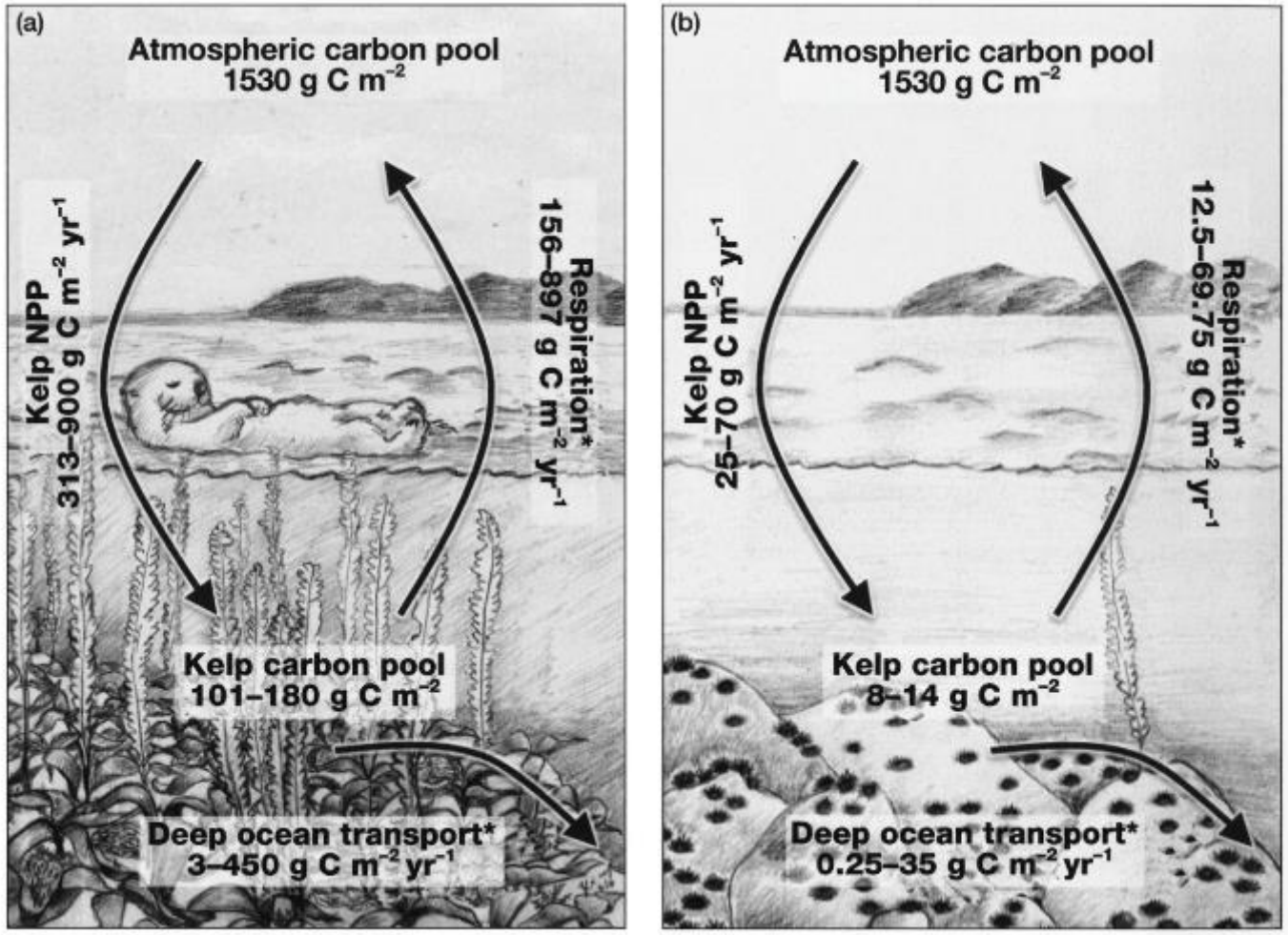
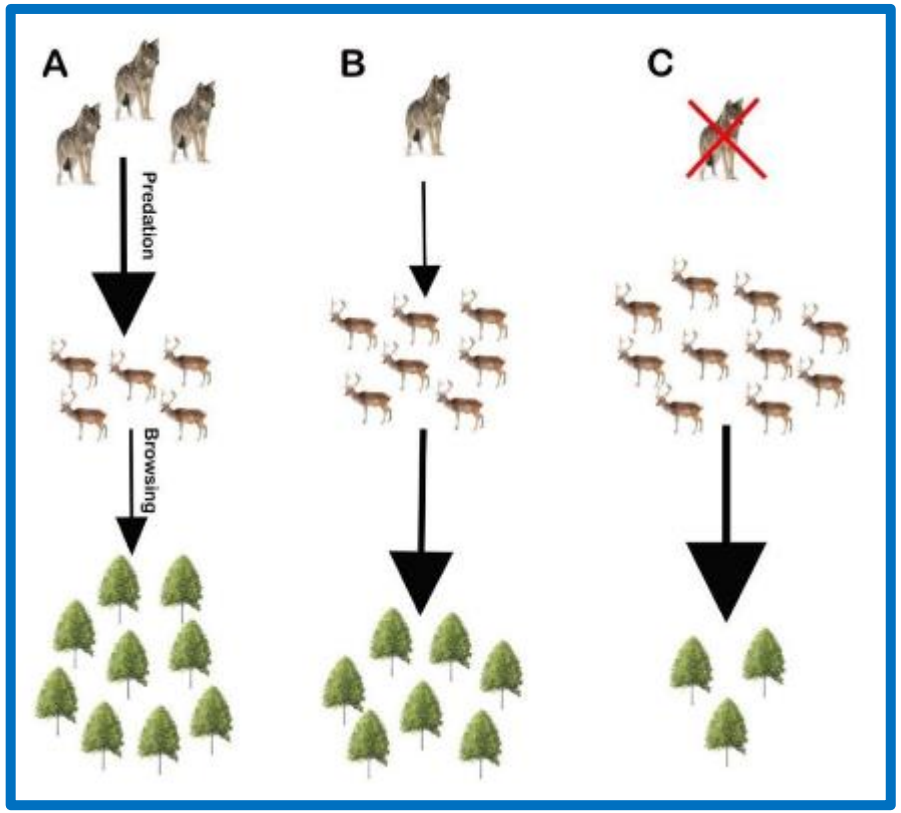
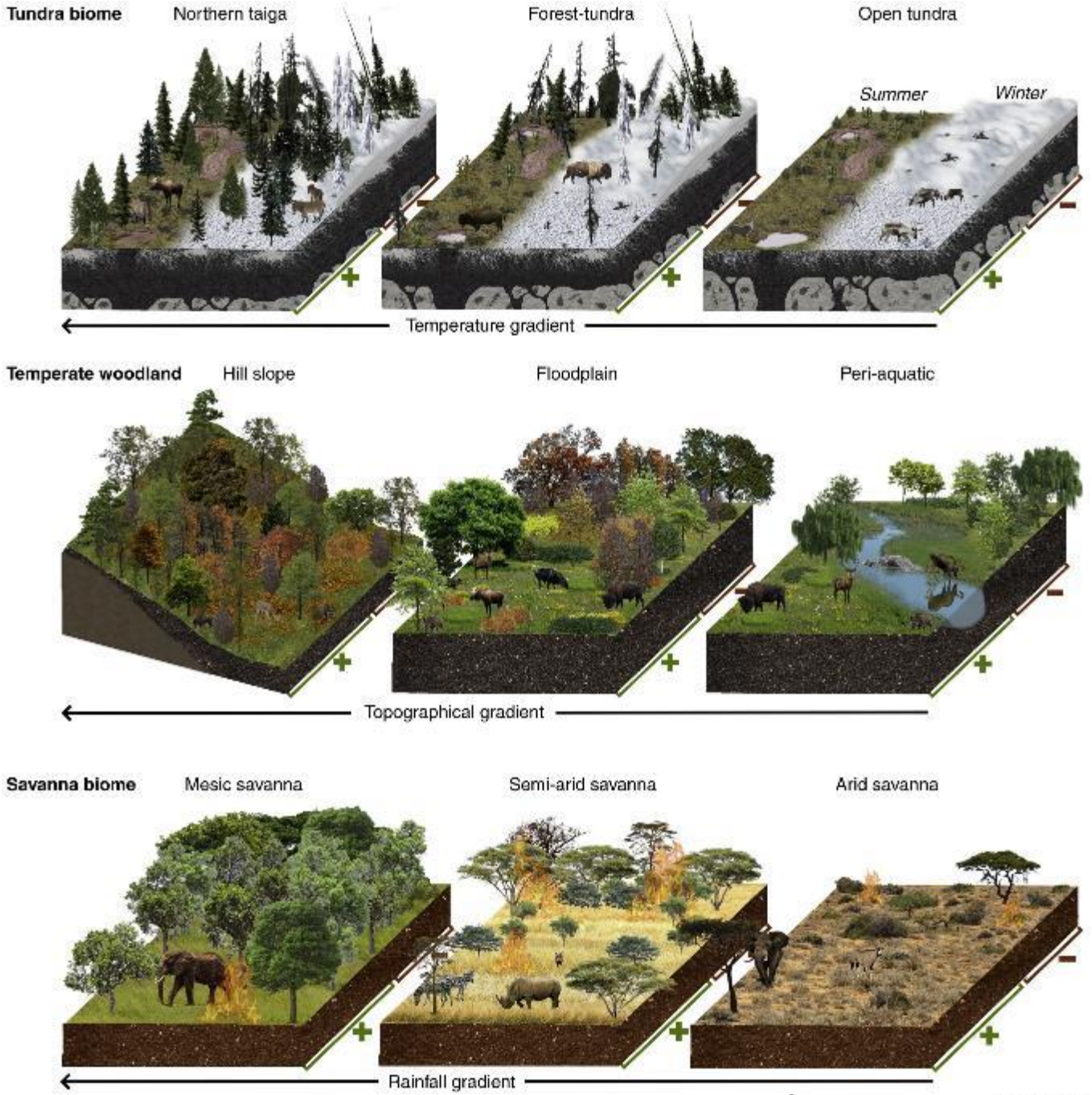


Figure 2. *(a) When occurring at ecologically effective densities, sea otters reduce sea urchins, resulting in large kelp standing stocks*

Wilmers et al. 2012 Front. Ecol Env.



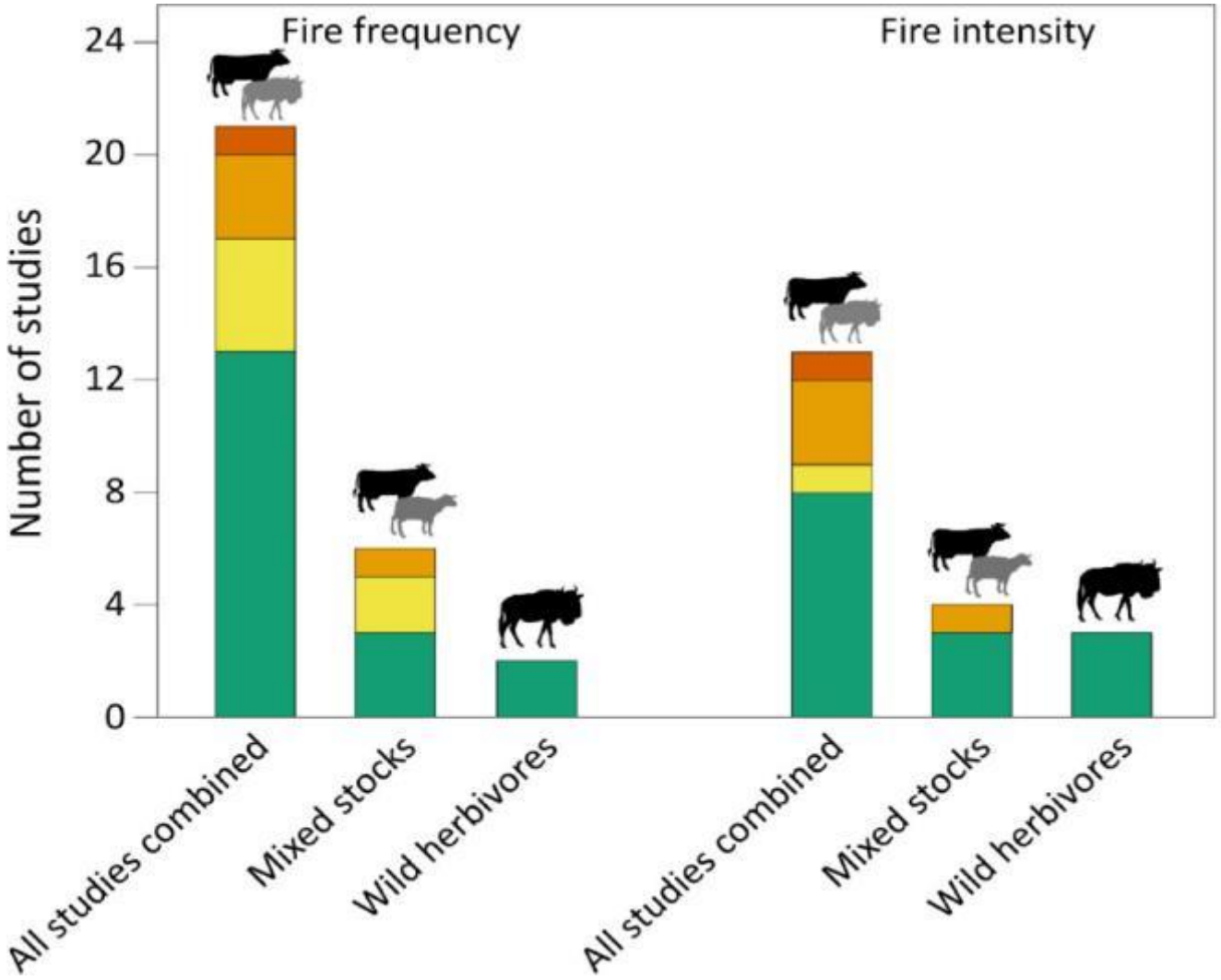
Allen, S. 2020, Routes

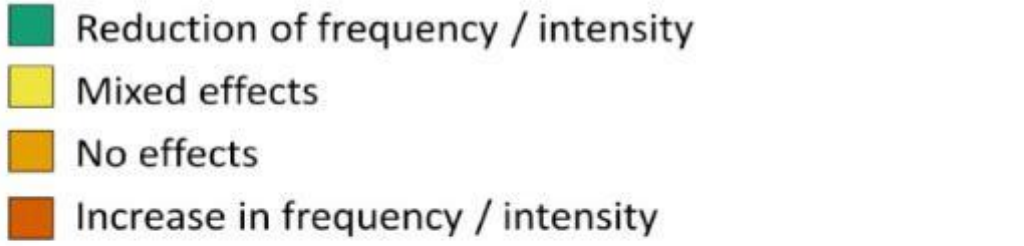


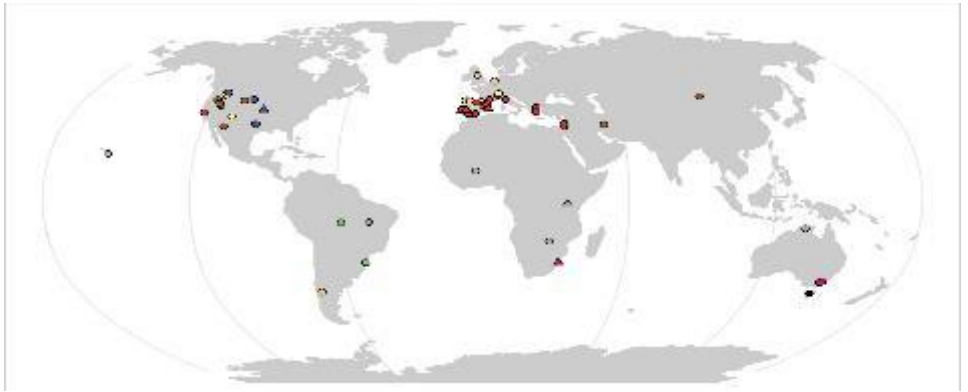
Mahli et al. 2022, Current Biology

Current Biology

Large wild herbivores ALWAYS reduce fire







Rouet-Leduc 2021, JoAppEcol.

Flooding

The river master

Erosion

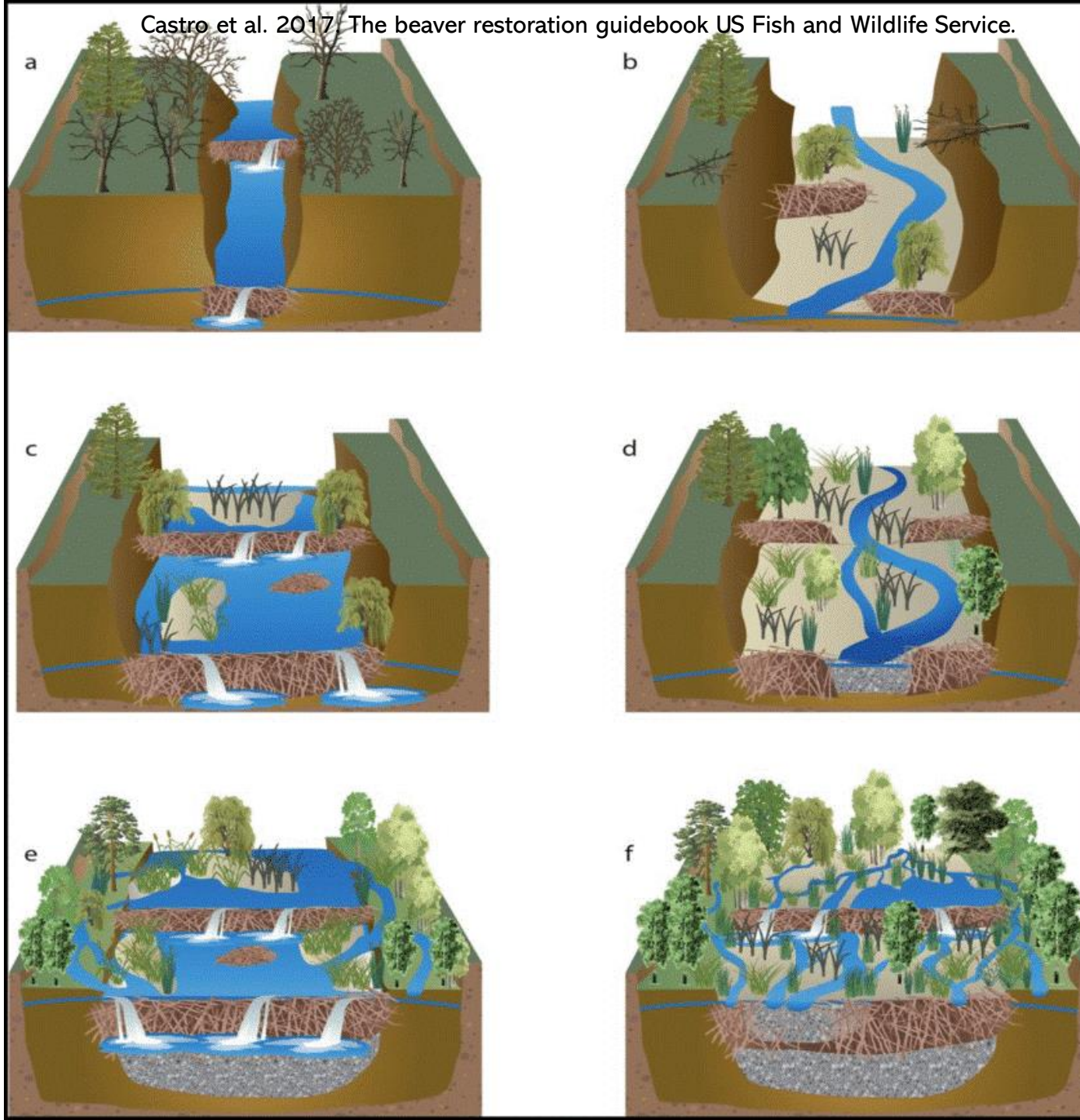
Drought

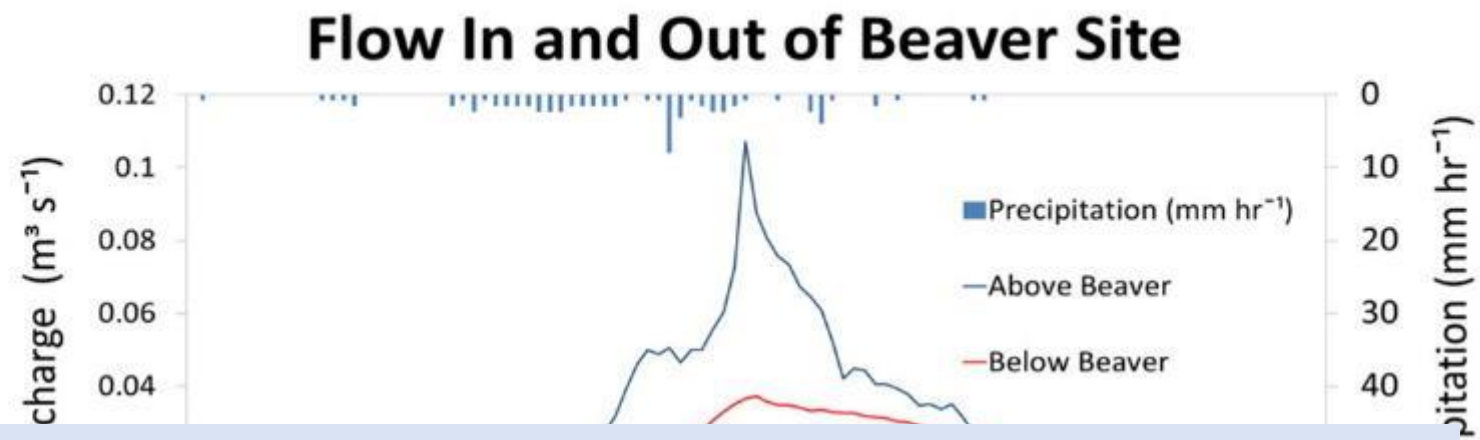
Water flow

Diversity

Credits: Adobestock/Ronnie Howard

Castro et al. 2017. The beaver restoration guidebook US Fish and Wildlife Service.

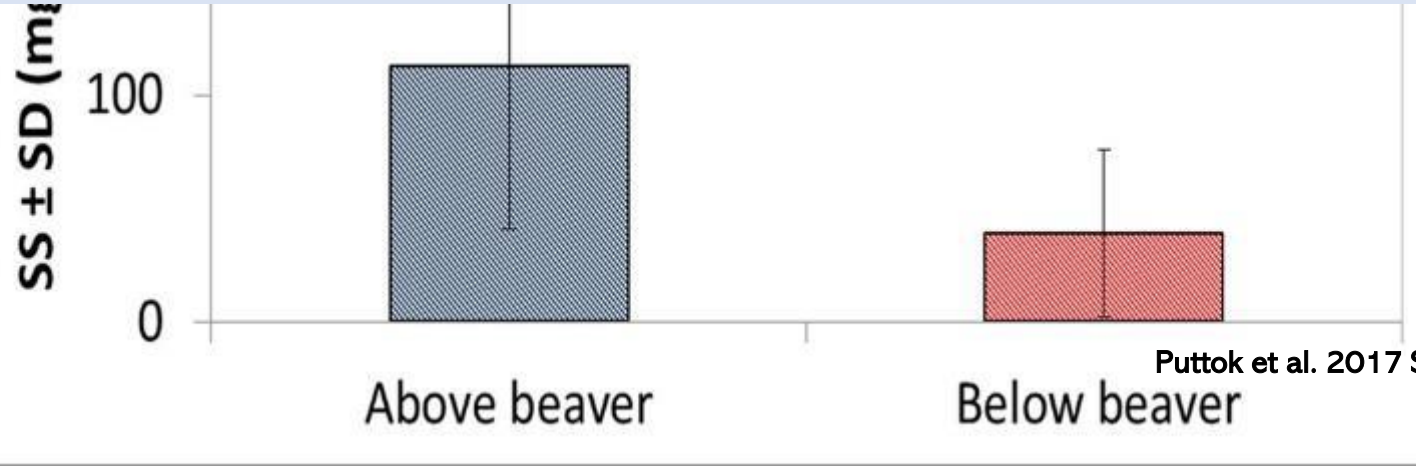




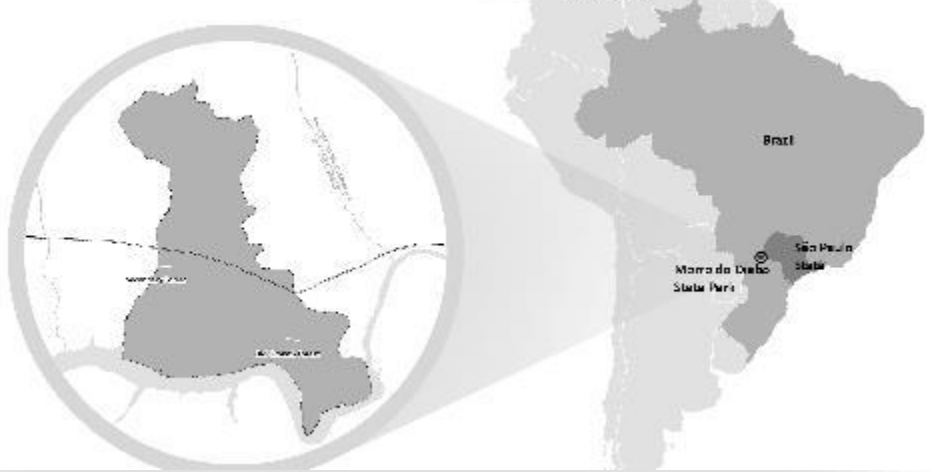
Increased water storage

Attenuated flow

Mitigation of diffuse pollution from intensively-managed grasslands



Puttok et al. 2017 Sci Tot Env.

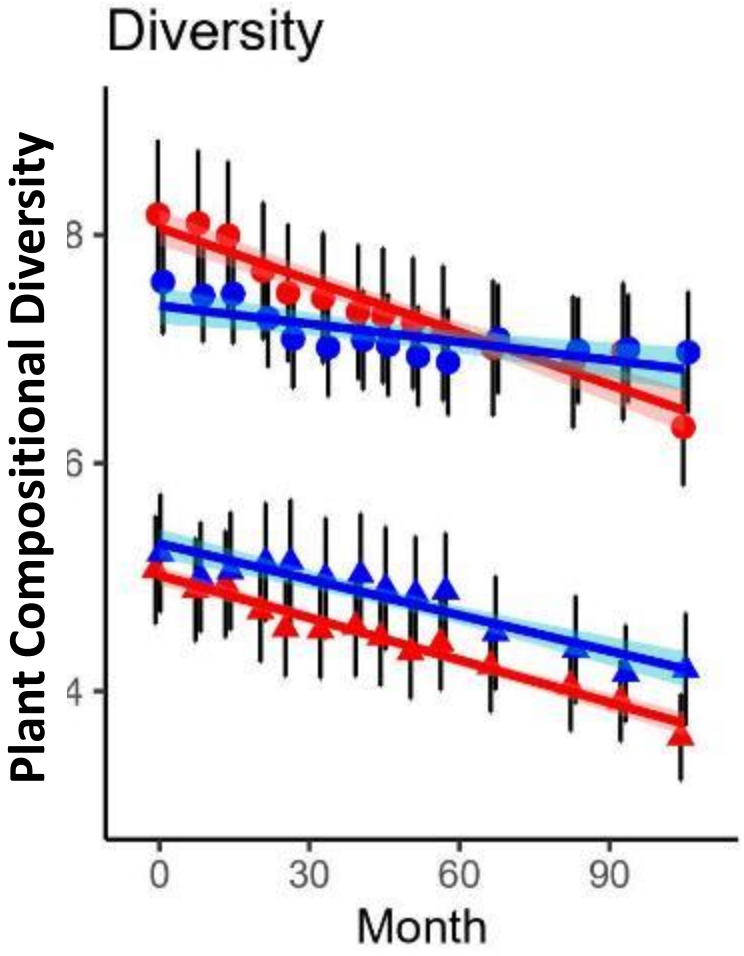


Villar et al. 2022, JoAppEcol.

BIODIVERSITY

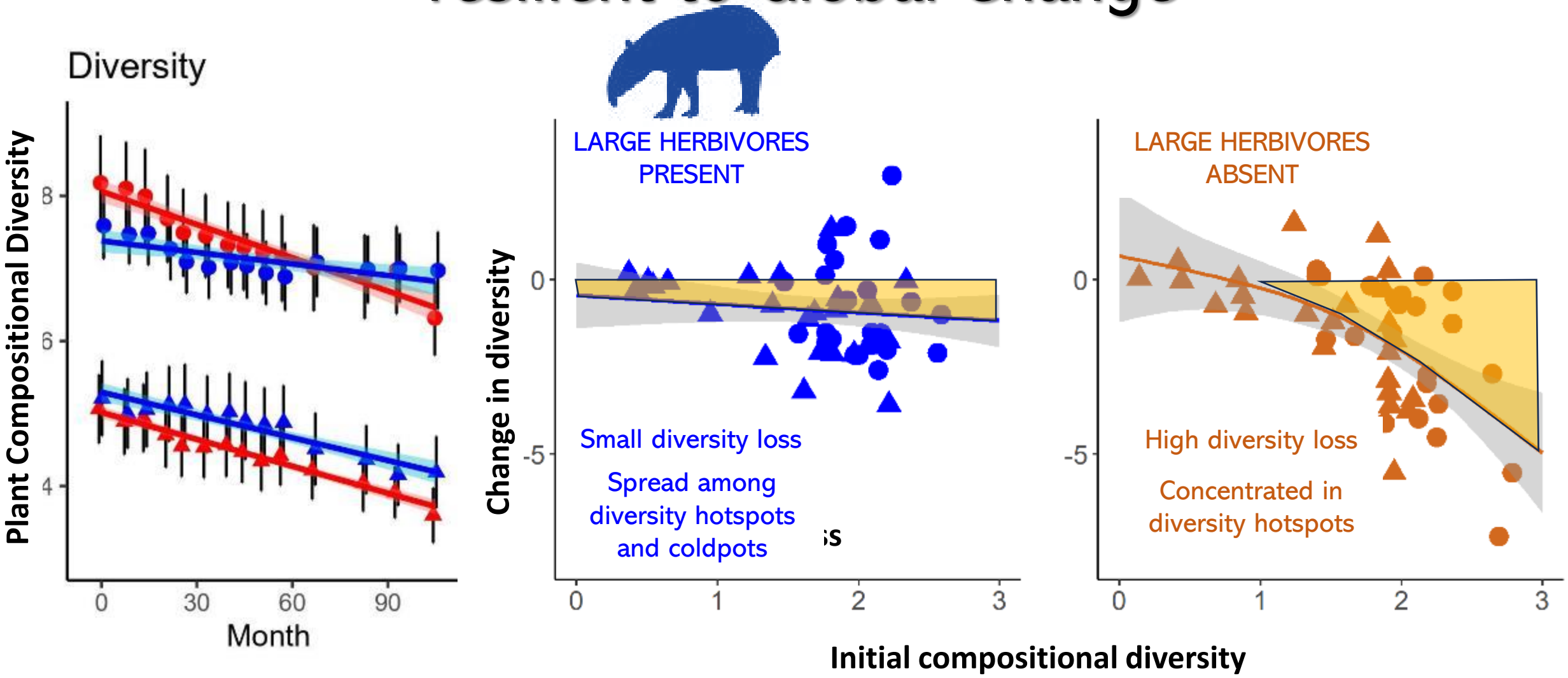
Can large wildlife safeguard biodiversity from Climate Change?

Large wildlife make biodiversity hotspots more resilient to Global Change

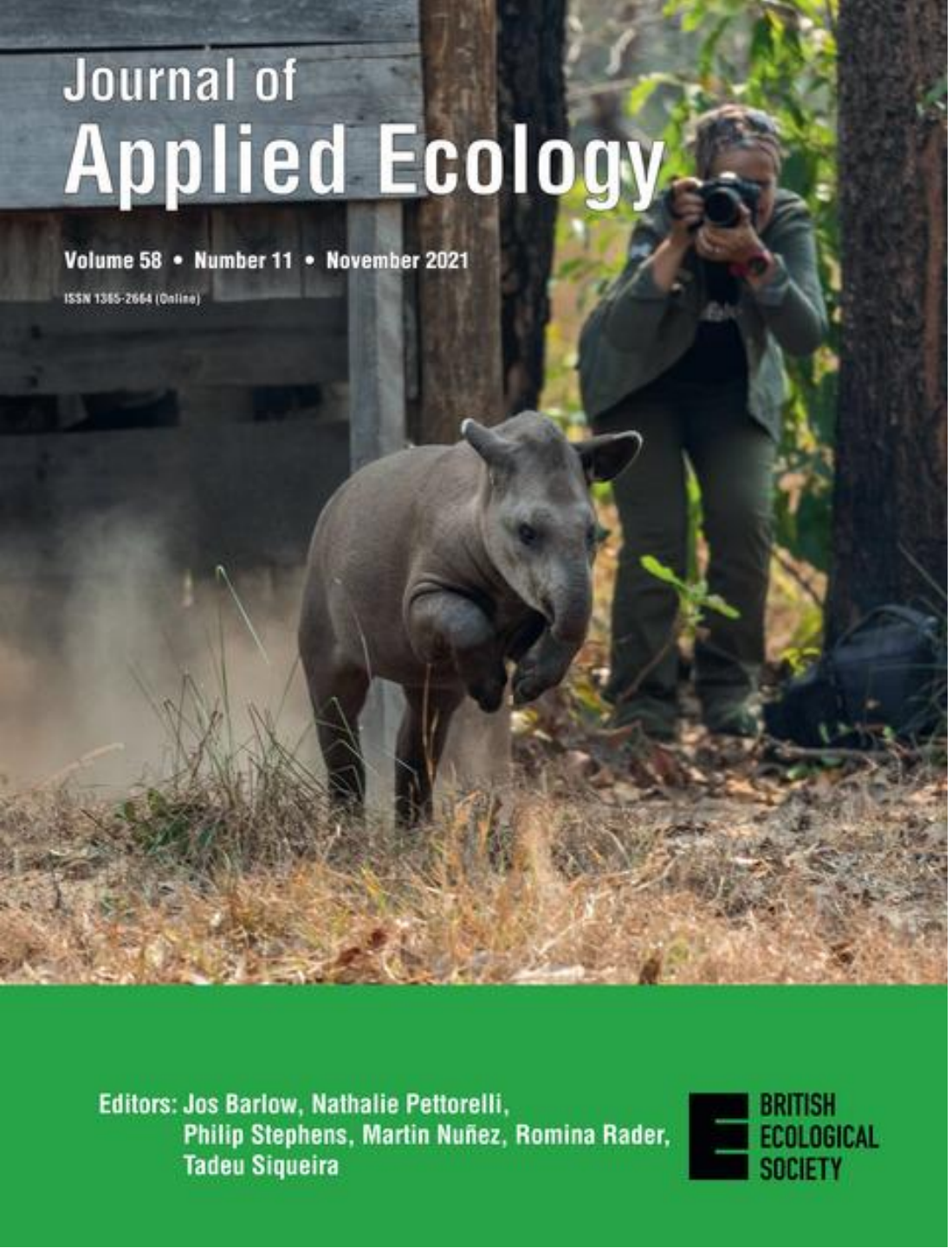


Villar et al. 2022, JoAppEcol.

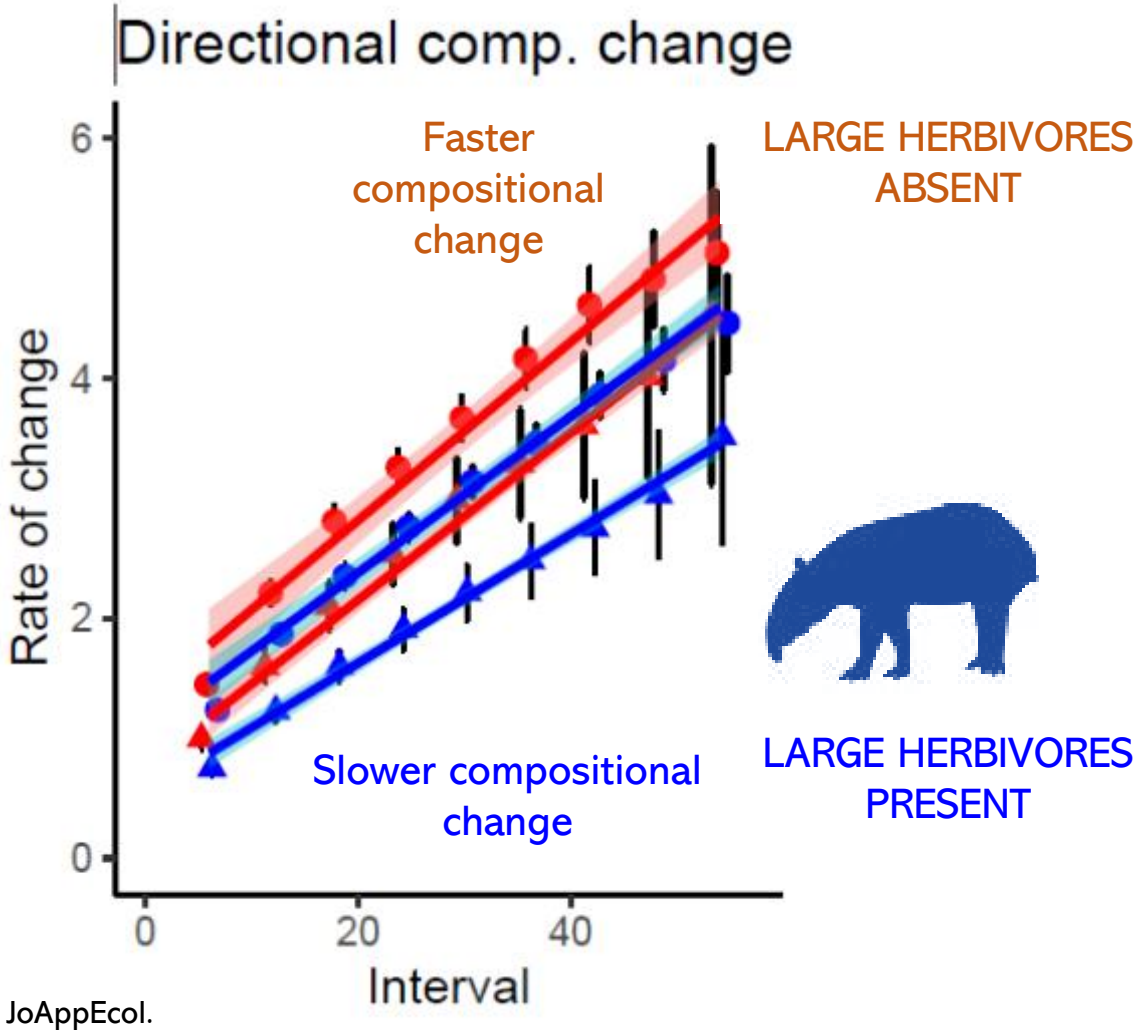
Large wildlife make biodiversity hotspots more resilient to Global Change



Villar et al. 2022, JoAppEcol.



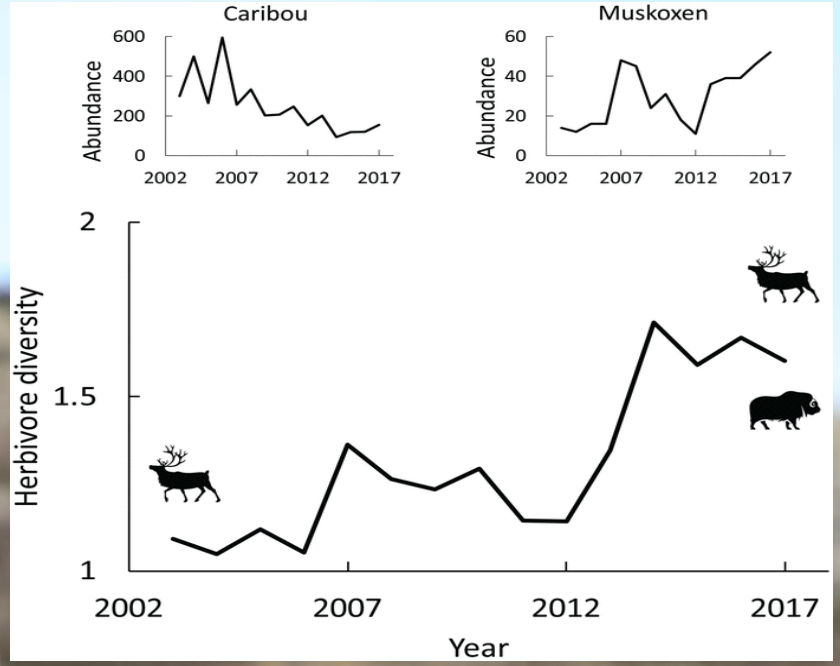
Large frugivores slow down compositional change & invasion of new species

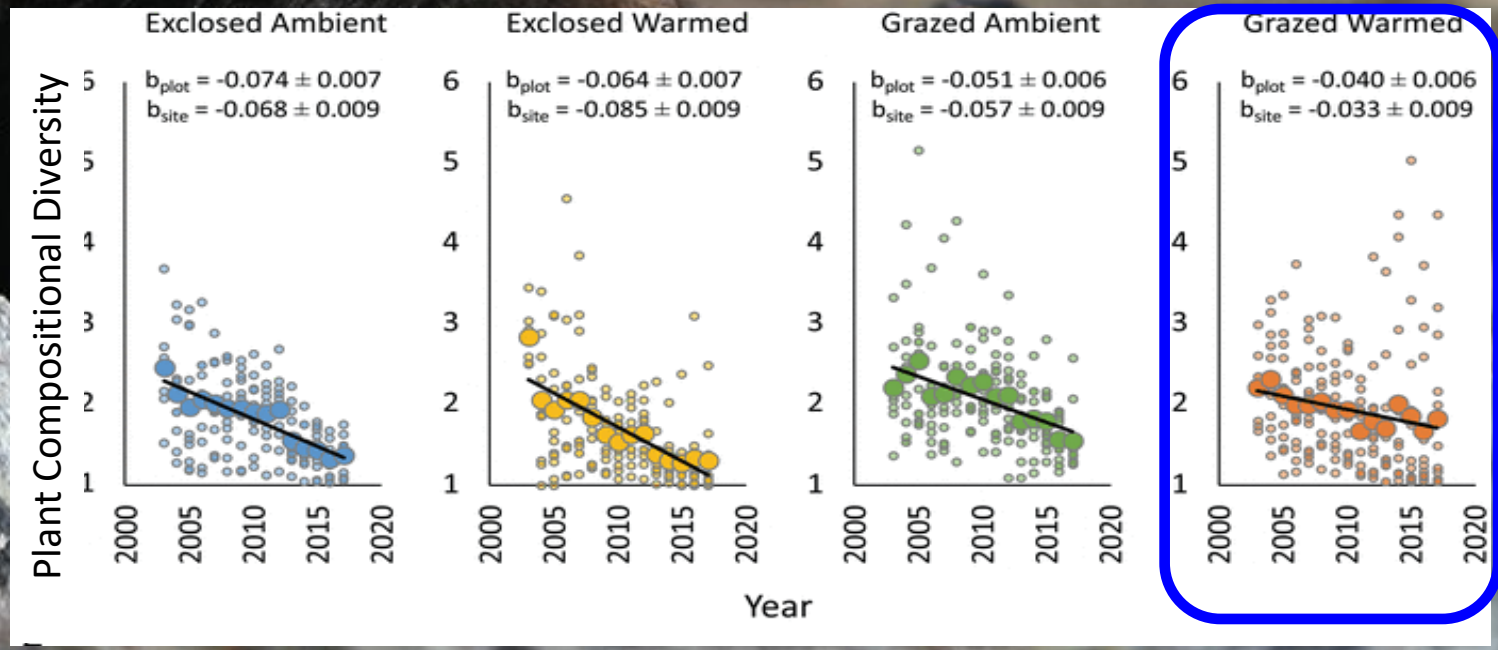


Villar et al. 2022, JoAppEcol.

Large herbivore diversity increases plant diversity in a warming world

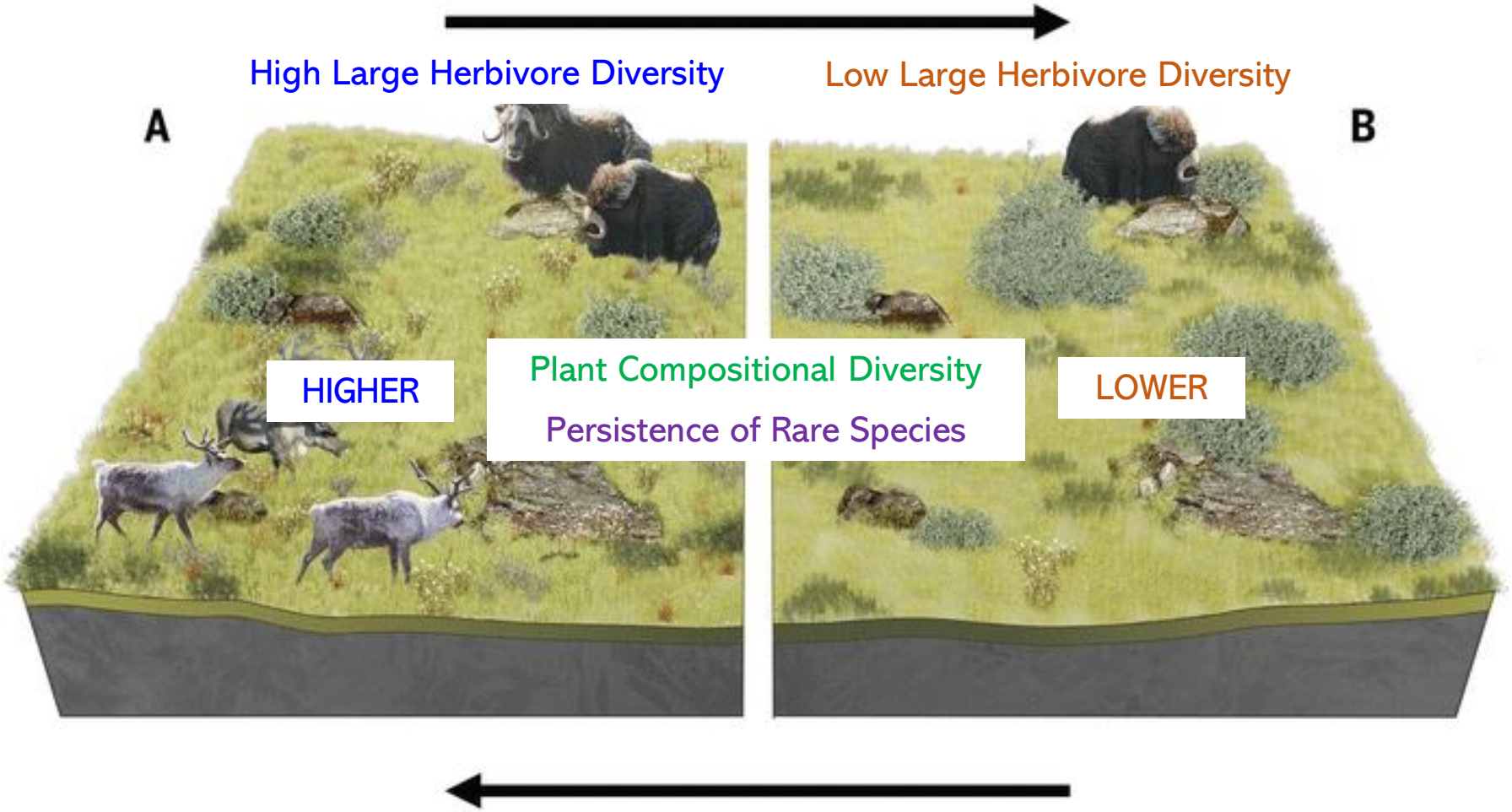
Post et al. 2023, Science





Photocredits: E. Post

Warming with lower or declining herbivore diversity and abundance



Warming with higher or increasing herbivore diversity and abundance

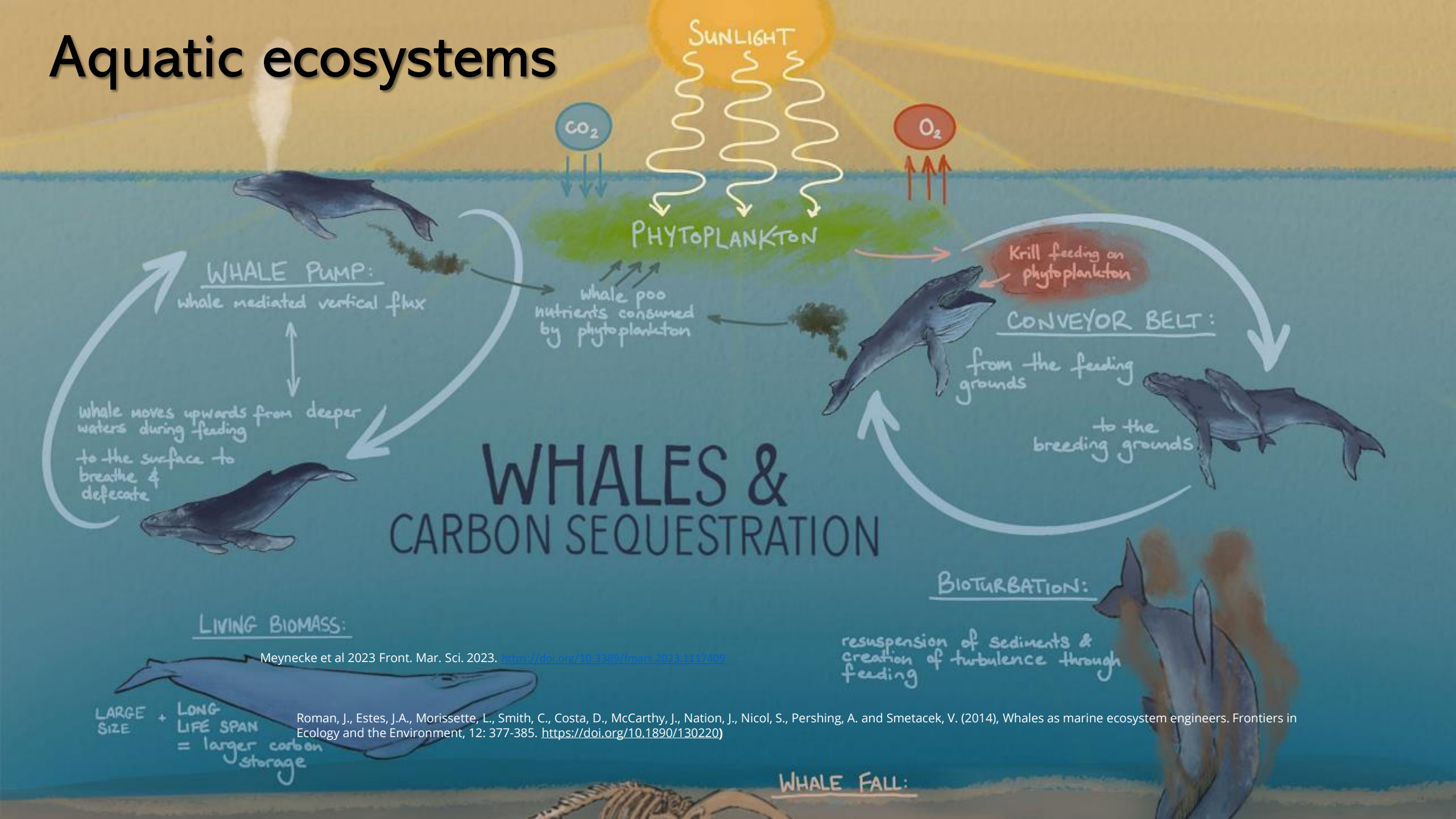
Post et al. 2023, Science

Post et al. 2022, Sci. Rep.

Work in progress

Credits: Christopher Swann Science Source

Aquatic ecosystems



Meynecke et al 2023 Front. Mar. Sci. 2023. https://doi.org/10.3389/fmars.2023.1117409

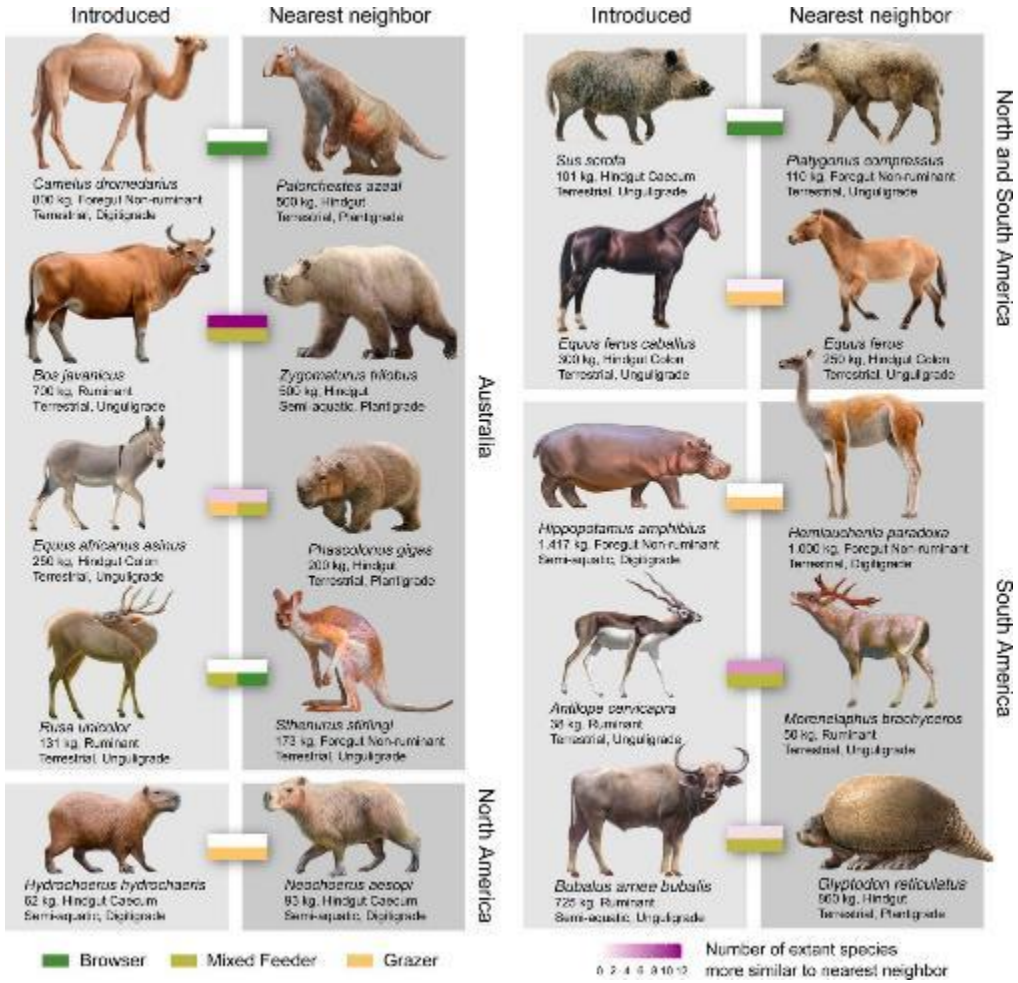
Roman, J., Estes, J.A., Morissette, L., Smith, C., Costa, D., McCarthy, J., Nation, J., Nicol, S., Pershing, A. and Smetacek, V. (2014), Whales as marine ecosystem engineers. Frontiers in Ecology and the Environment, 12: 377-385. https://doi.org/10.1890/130220)

Can surrogates of wild/extinct species help in the fight against Climate Change ?

Domestic Livestock

Image: Collins dictionary

Introduced species



Lundgren et al., 2020 PNAS

Trophic Rewilding

Gelderse Poort, The Netherlands

Spatial & structural dimensions of large wildlife effects on Climate Change mitigation and adaptation

Structural heterogeneity

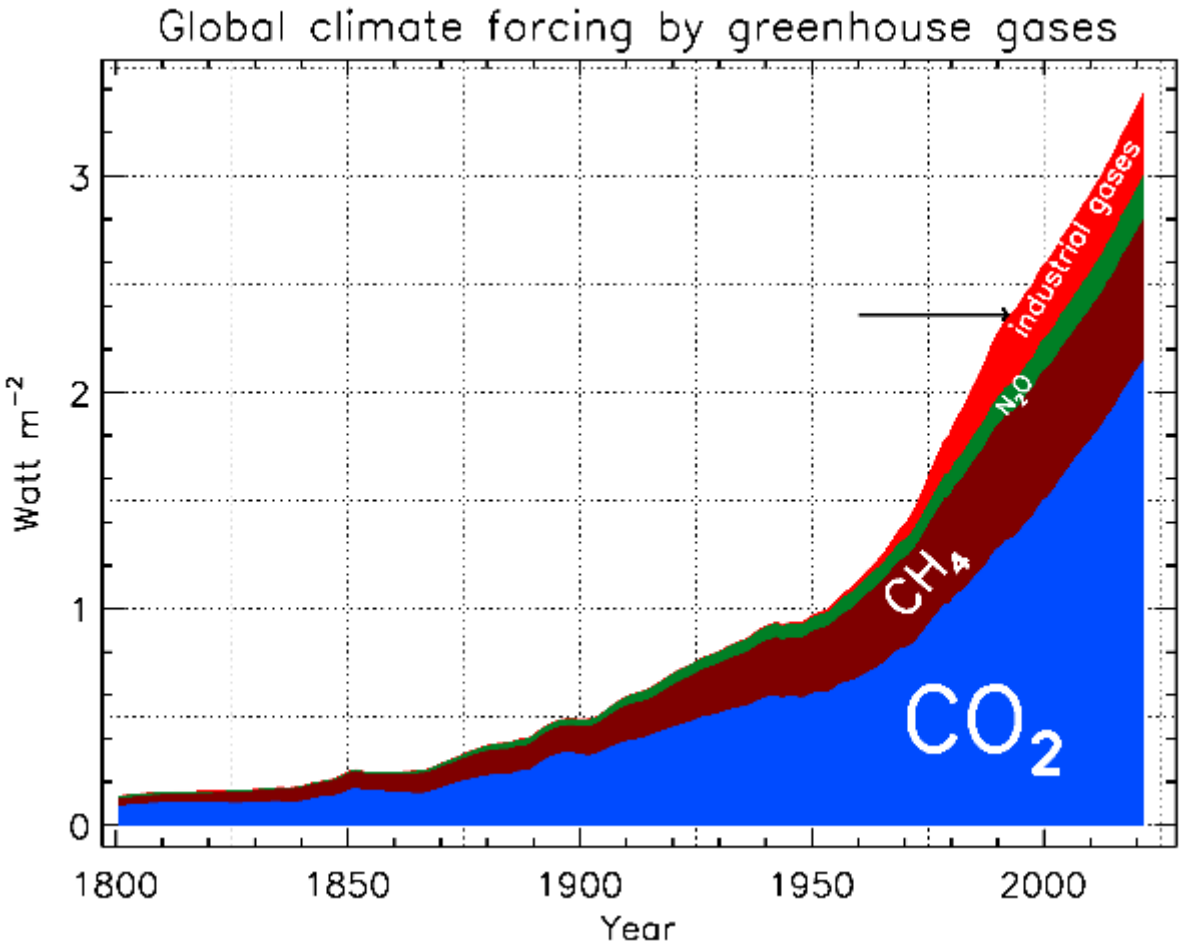
Souza, et al. 2022 JoEco.

Ecology of Fear

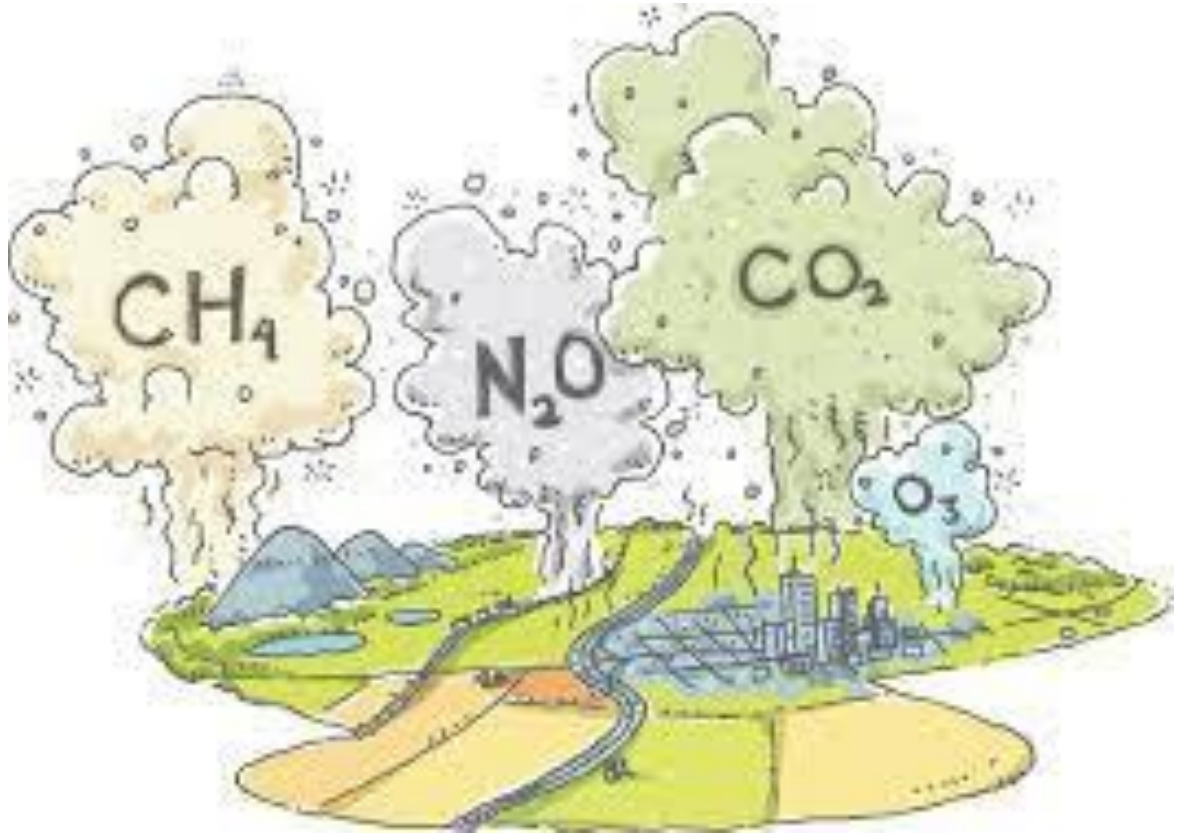
Landscape mosaics

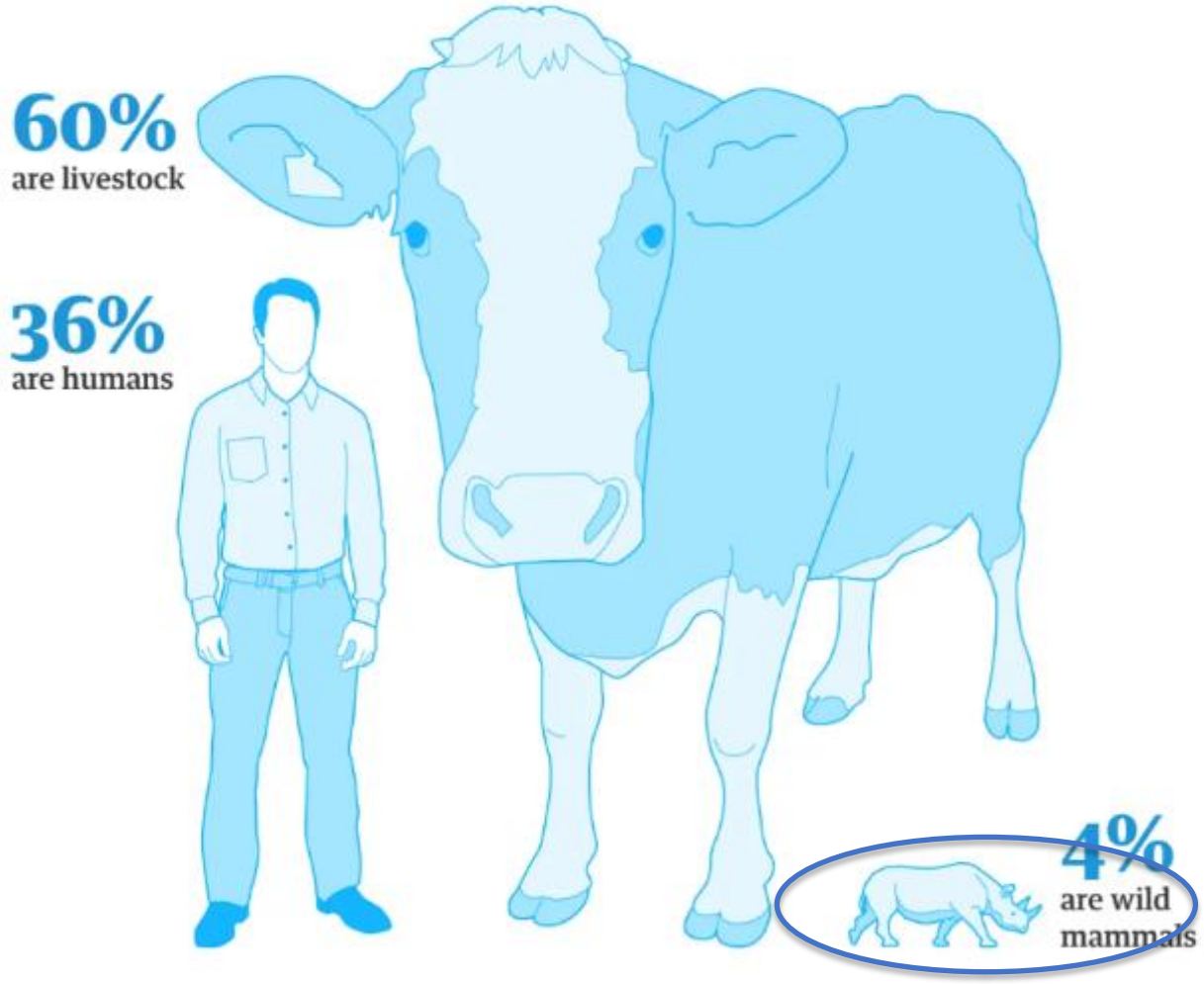
Gelderse Poort, The Netherlands

Large wildlife effects on Soil Greenhouse Emissions?



https://gml.noaa.gov/ccgg/ghgpower/





We matter for Climate Change M & A

Bar-Or et al. (2018), PNAS

We need to help large wildlife to help us with Climate

Credit: Steve Bloom Images Alamy

Netherlands Institute of Ecology

Nacho Villar

nachoprad@gmail.com

@NachomanVillar

nachoman.villar.1

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