





# Natural Hazards and Disaster

## Lab 11: Impacts of Modern Global and Climate Change

- Impacts
- Questions

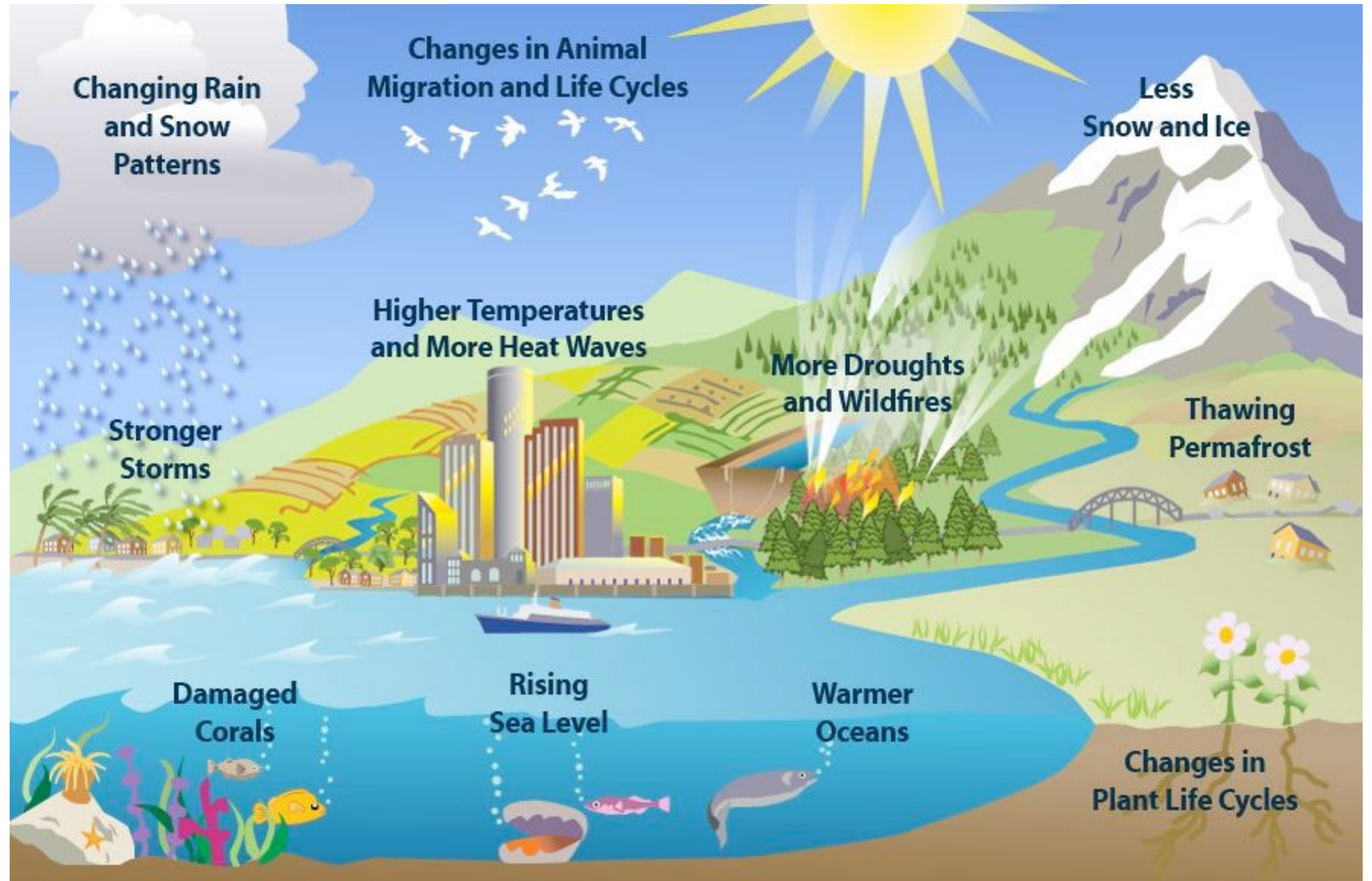




What are the  
Impacts of  
Climate Change?



## What are the Impacts of Climate Change?



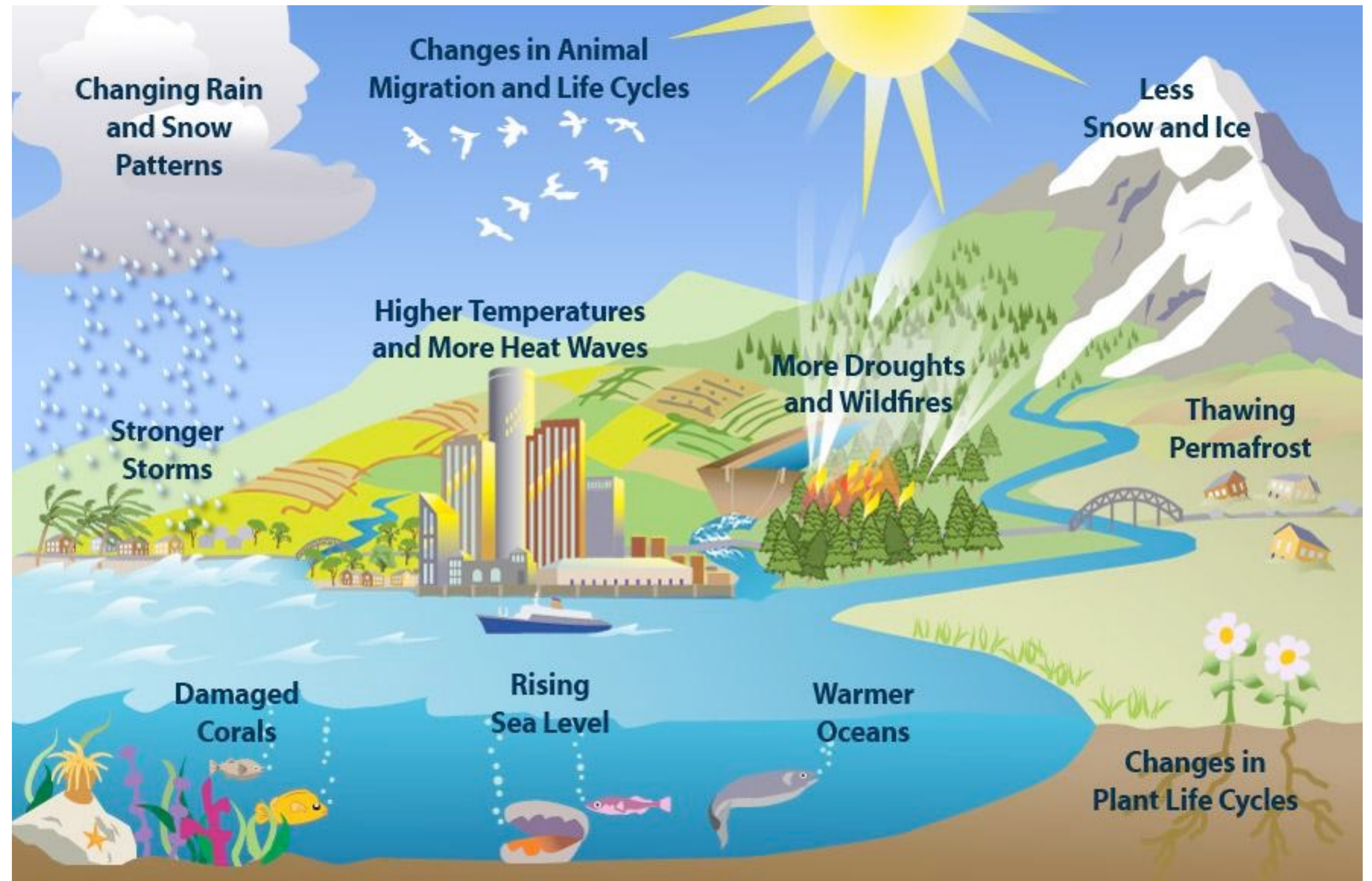


## What are the Impacts of Climate Change?

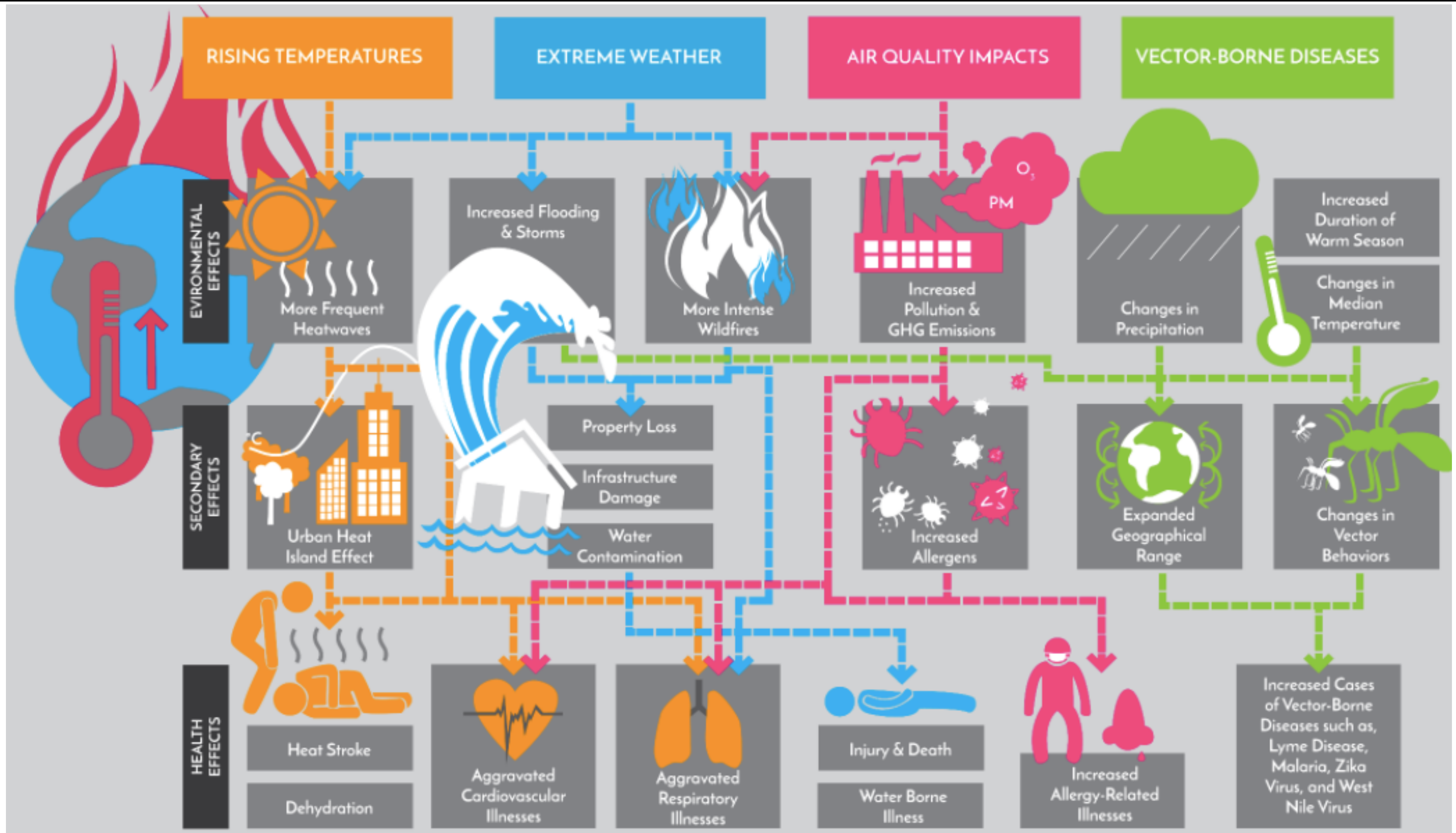
... and there is more:

- health
- supply chains
- mass extinction
- water security
- food security
- migration
- social unrest

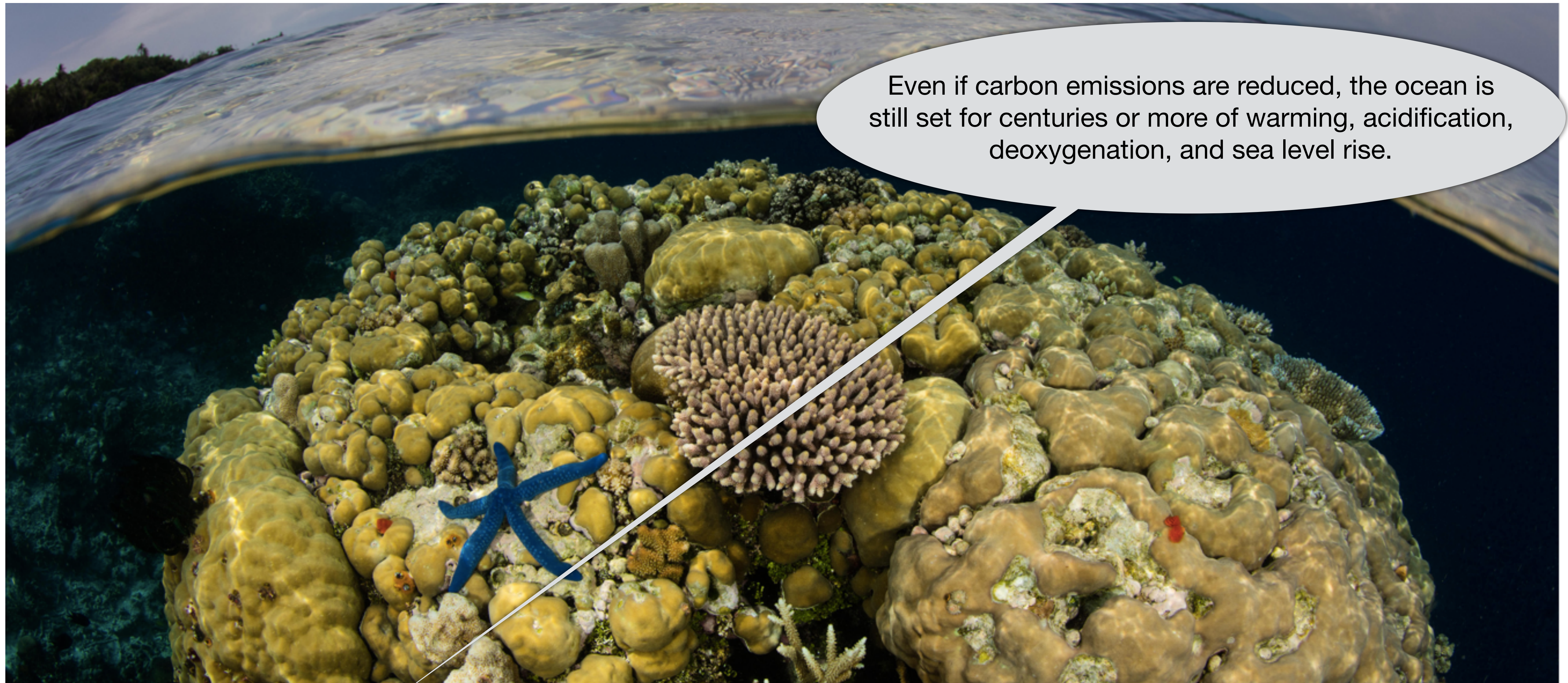
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Even if carbon emissions are reduced, the ocean is still set for centuries or more of warming, acidification, deoxygenation, and sea level rise.

Even if carbon emissions are reduced, the ocean is still set for centuries or more of warming, acidification, deoxygenation, and sea level rise. Photo by Ethan Daniels/Alamy Stock Photo

## When It Comes to Climate Change, the Ocean Never Forgets



REPORT

## Large-scale ocean deoxygenation during the Paleocene-Eocene Thermal Maximum

Weiqli Yao<sup>1,\*</sup>, Adina Paytan<sup>2</sup>, Ulrich G. Wortmann<sup>1</sup>

+ See all authors and affiliations

Science 24 Aug 2018:  
Vol. 361, Issue 6404, pp. 804-806  
DOI: 10.1126/science.aar8658

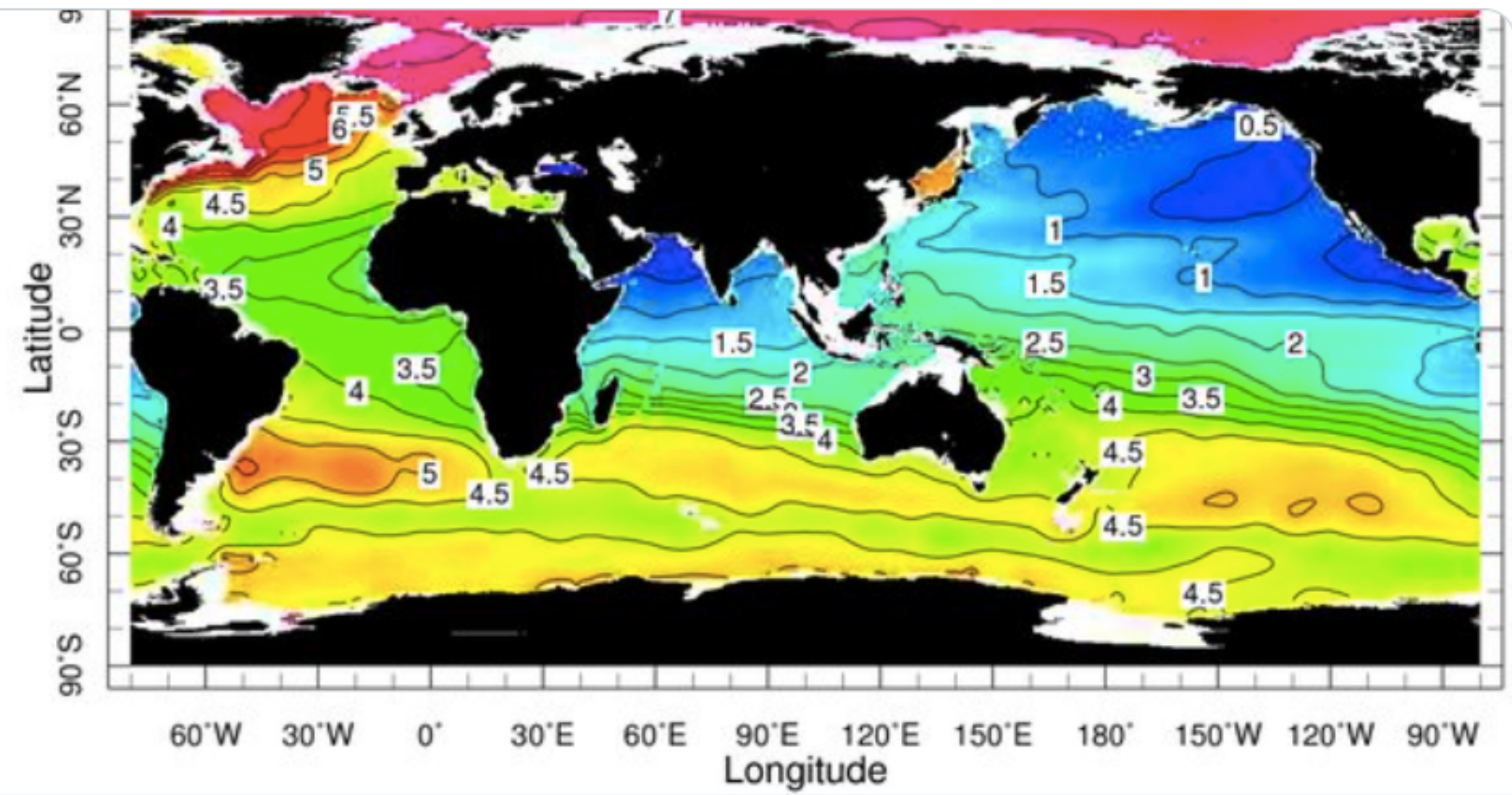
### Fishin' gone?

Because gas solubility decreases as temperatures increase, global warming is likely to cause oxygen loss from the oceans. This could have a detrimental impact on fish populations, the fishing industry, and global food availability. Have such impacts occurred before? Yao *et al.* report sulfur isotopic data from the Paleocene-Eocene Thermal Maximum, an interval around 55 million years ago when atmospheric carbon dioxide concentrations and global temperatures were also high. They found widespread anoxia and resulting high concentrations of hydrogen sulfide, which is toxic to marine organisms. Similar effects could have severe negative effects on ocean ecosystems.

Science, this issue p. **804**

### Abstract

The consequences of global warming for fisheries are not well understood, but the geological record demonstrates that carbon cycle perturbations are frequently associated with ocean deoxygenation. Of particular interest is the Paleocene-Eocene Thermal Maximum (PETM), where the carbon dioxide input into the atmosphere was similar to the IPCC RCP8.5 emission scenario. Here we present sulfur-isotope data that record a positive 1 per mil excursion during the PETM. Modeling suggests that large parts of the ocean must have become sulfidic. The toxicity of hydrogen sulfide will render two of the largest and least explored ecosystems on Earth, the mesopelagic and bathypelagic zones, uninhabitable by multicellular organisms. This will affect many marine species whose ecozones stretch into the deep ocean.



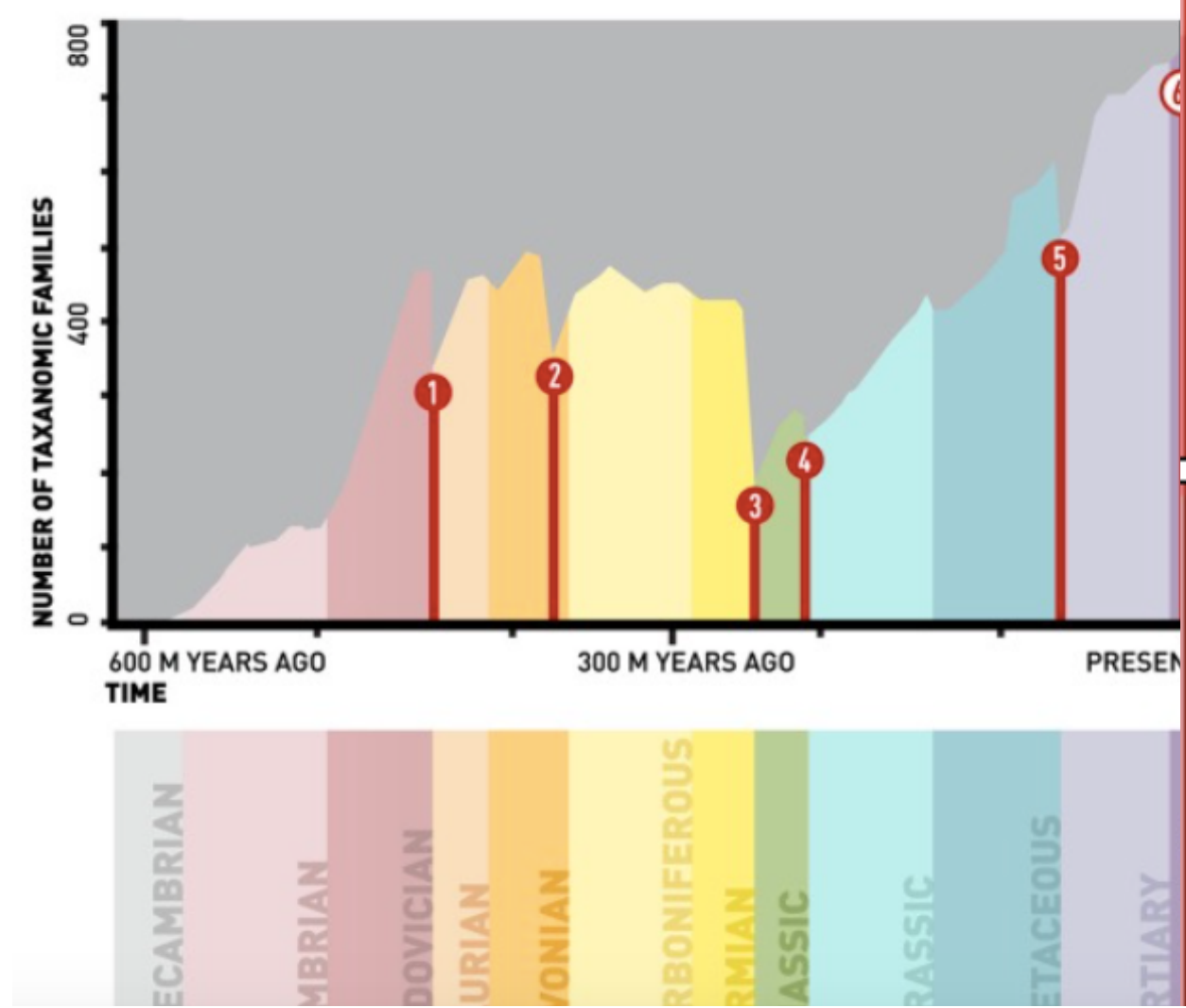


# Impacts

## DEEP DIVE: MASS EXTINCTIONS

BY JULIE ROSSMAN & CLARE SMITH MARASH

World Science Festival  
worldsciencefestival.com



1	END ORDOVICIAN	<p><b>85%</b> of living organisms lost</p> <p>WHAT HAPPENED: Glaciation followed by a rebound of a greenhouse climate.</p> <p>HARD-HIT GROUPS: TRILOBITES, BRACHIOPODS, BRIGIDIAKS, ECHINODERMS, GRAPTOLITES</p>
2	LATE DEVONIAN	<p><b>70%</b> of all marine species lost</p> <p>WHAT HAPPENED: Lack of oxygen in the oceans, rising sea levels, and global cooling.</p> <p>HARD-HIT GROUPS: REEF ENVIRONMENTS, OSTRACODERMS &amp; PLACODERMS, STROMATOPORIDS, RUGOSA &amp; TABULATA, TRILOBITES</p>
3	END PERMIAN (THE GREAT DYING)	<p><b>96%</b> of all species lost</p> <p>WHAT HAPPENED: Extremely dry, hot conditions led to animal and plant decline, and a large volcanic eruption pushed carbon dioxide into the atmosphere, raising temperatures and lowering oxygen in the ocean. It took 10-20 million years for life to recover its diversity after this event.</p> <p>HARD-HIT GROUPS: TRILOBITES, EURYPTERIDS, FOSSILING FORAMINIFERA, ACANTHODIANS, MONURA AND OTHER INSECTS</p>
4	END TRIASSIC	<p><b>76%</b> of all species lost</p> <p>WHAT HAPPENED: Extreme volcanic activity, which would eventually break apart the supercontinent of Pangaea, raised global temperatures and acidified the ocean. There is still a great deal of controversy surrounding the main cause of extinction during this period.</p> <p>HARD-HIT GROUPS: THERIAZODON, MASTODONTIAURUS, BRACHIOPODS, AMPHONITES, CONODONTS</p>

### 6? ????% of all species lost

WHAT'S HAPPENING: Some scientists think the sixth major extinction event started 10,000 years ago when humankind began to dominate the Earth, with extinctions tied to a wide array of causes including hunting, habitat destruction, pollution, and global climate change.

### WWF - LIVING PLANET REPORT 2016

WWF REPORT INT 2016

THIS REPORT HAS BEEN PRODUCED IN COLLABORATION WITH ZSL LET'S WORK FOR WILDLIFE and Global Freshwater Network

Living Planet Report 2016  
Work and resilience in a new era

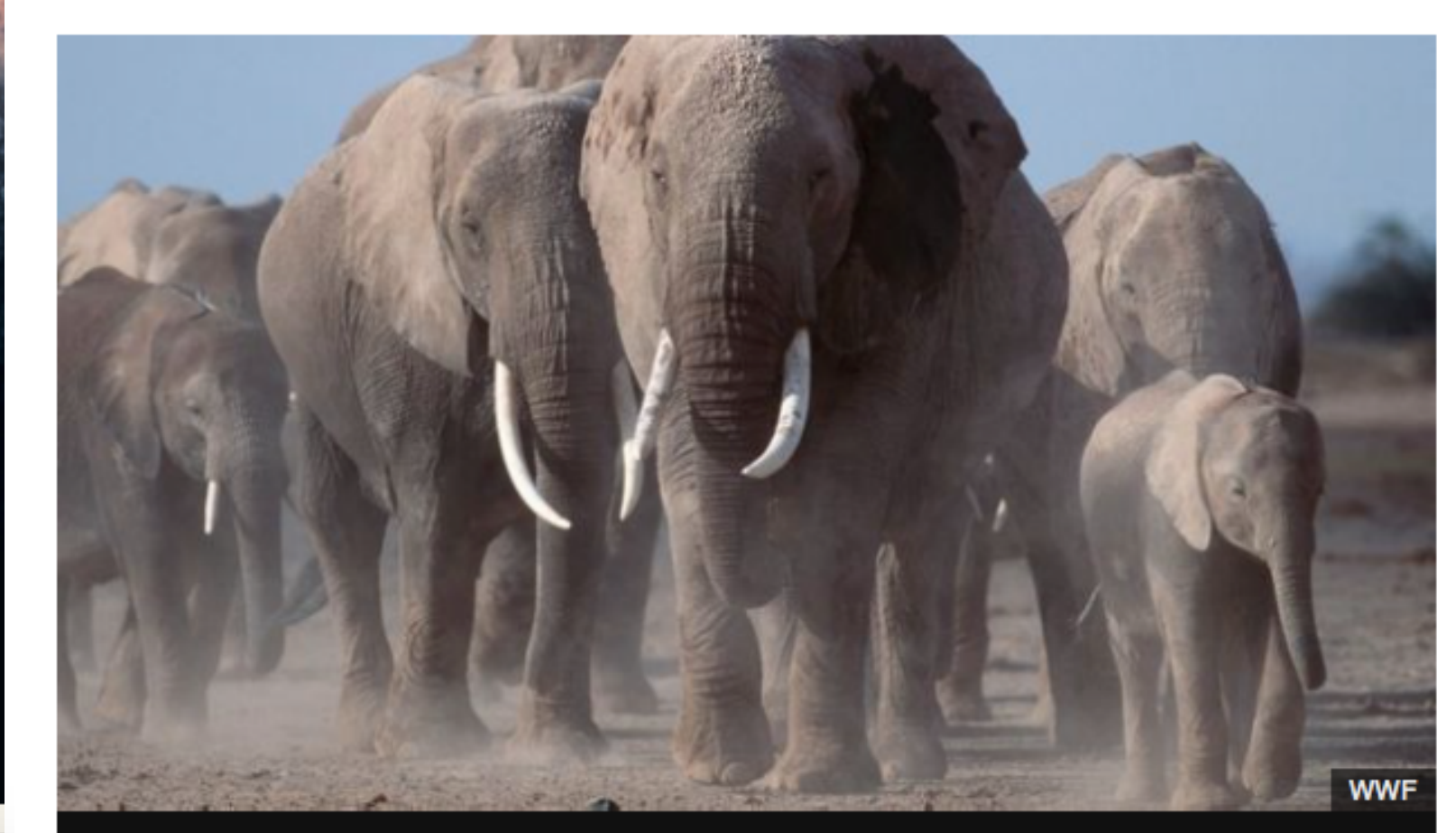
Science & Environment

### World wildlife 'fallen 81% since 1970'

By Rebecca Morelle, Science Correspondent, BBC

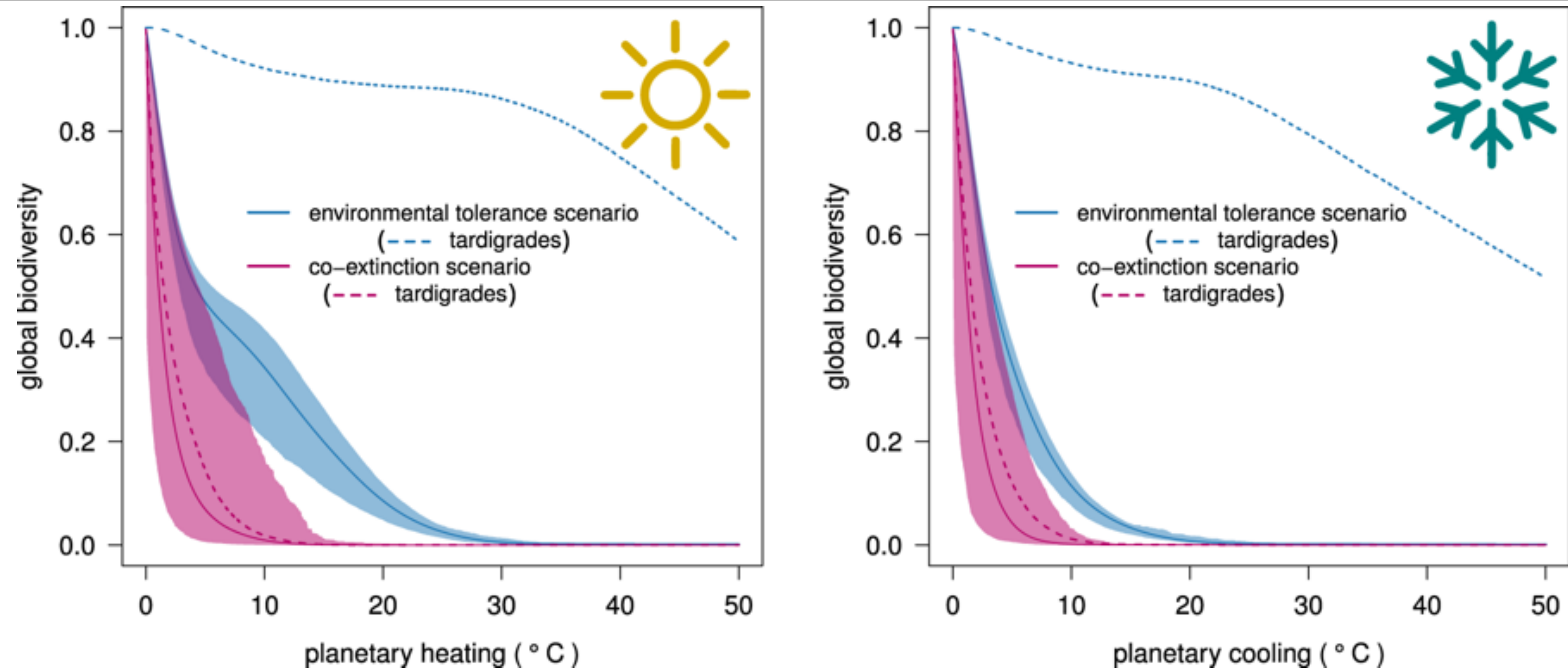
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"We do see particularly strong declines in freshwater species alone, the decline stands at 81% since 1970. This is related to the way water is used and taken out of fresh water systems, and also the fragmentation of freshwater systems through dam building, for example."



Current extinction rates:  
 300 times background rate for birds  
 80,000 times background rate for mammals

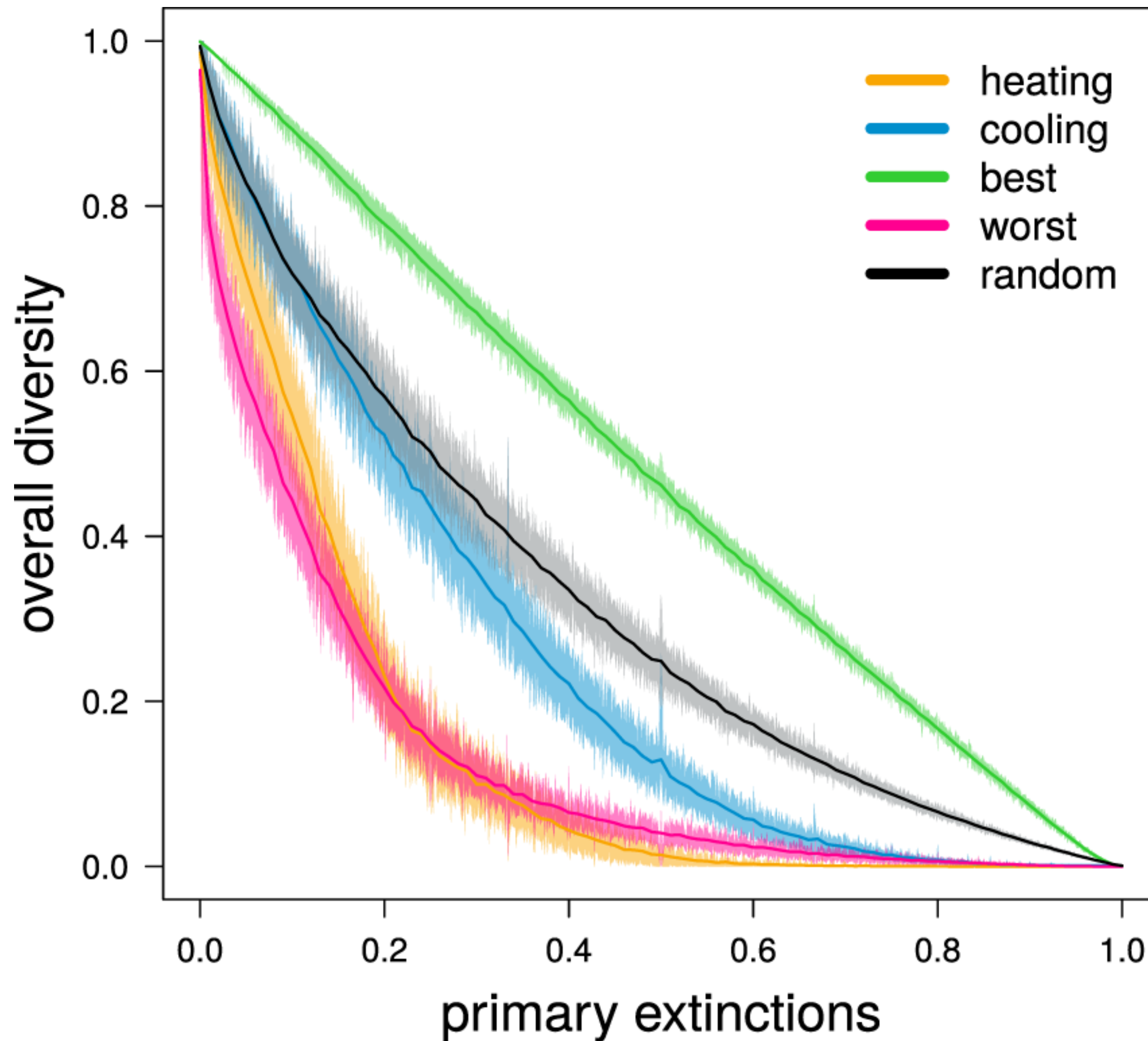




Co-extinctions reduce the robustness of planetary life to catastrophe. Response of global diversity to environmental change: progressive, monotonic increase ('planetary heating'; left panel) or decrease ('planetary cooling'; right panel) trajectories in local temperature. Species either go extinct based only on their tolerance to environmental conditions ('environmental tolerance' scenarios = blue curves), or where species go extinct not only when unable to cope with changed environmental conditions, but also following the depletion of their essential resources ('co-extinction' scenarios = magenta curves). Solid lines represent mean values, and shaded areas indicate the system boundaries (minimum-maximum) arising from 1000 randomly parametrized models (see Methods for details). Dotted lines show the decline in 'tardigrade' (extremophile) species richness in the environmental tolerance (blue) and in the co-extinction scenario (magenta) for both temperature trajectories.

Strona and Bradshaw, 2018



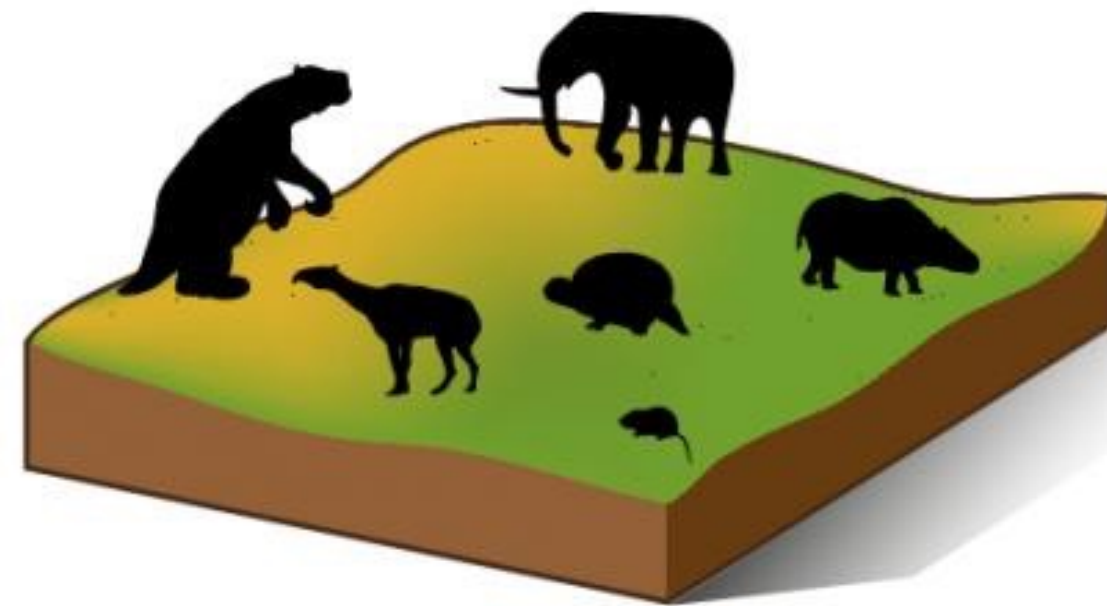


Co-extinctions reduce the robustness of planetary life to catastrophe. Response of global diversity to environmental change: progressive, monotonic increase ('planetary heating'; left panel) or decrease ('planetary cooling'; right panel) Simulated food webs are more robust to global cooling than to heating. We evaluated robustness by 'disassembling' a random sample of 1000 food webs. Disassembly consisted of removing species progressively from the least to the most tolerant to warm ('heating') or cold ('cooling') temperatures. We simulated co-extinctions after each species removal, and then plotted the curves depicting the (co-extinction driven) decline of local diversity following direct species removal. To obtain approximate upper and lower boundaries of robustness, we did two additional disassembly simulations for each food web by removing species in increasing ('best') or decreasing ('worst') order of their expected contribution to network persistence (measured as the number of associated resources per species). For each food web, we also obtained a reference curve by removing species in random order ('random'). Solid lines represent mean values, while shaded areas indicate 99% confidence intervals.

**Strona and Bradshaw, 2018**

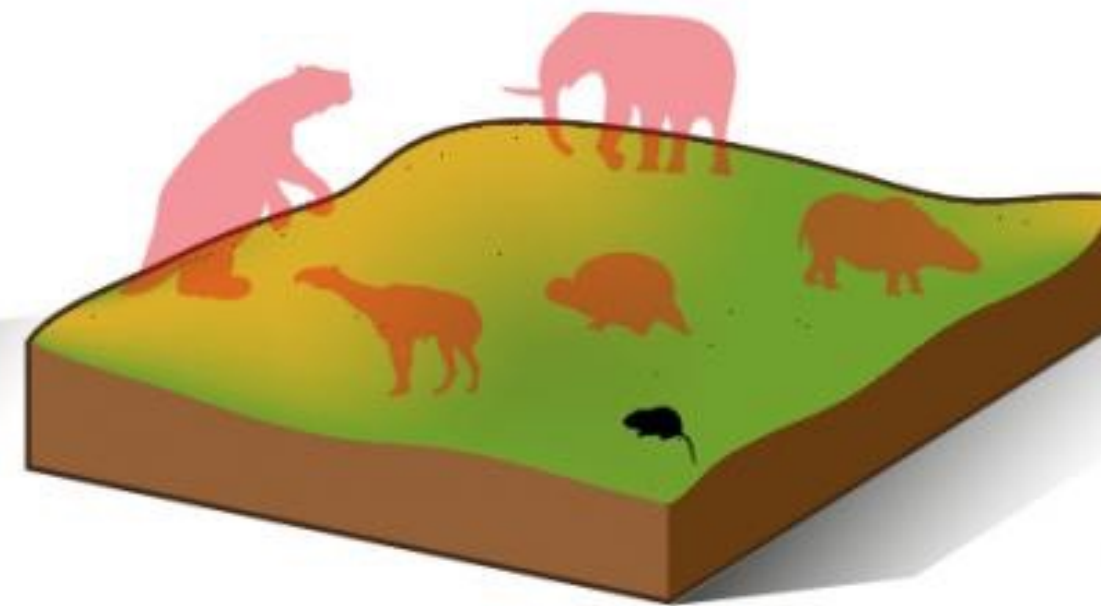


## The Ice Age



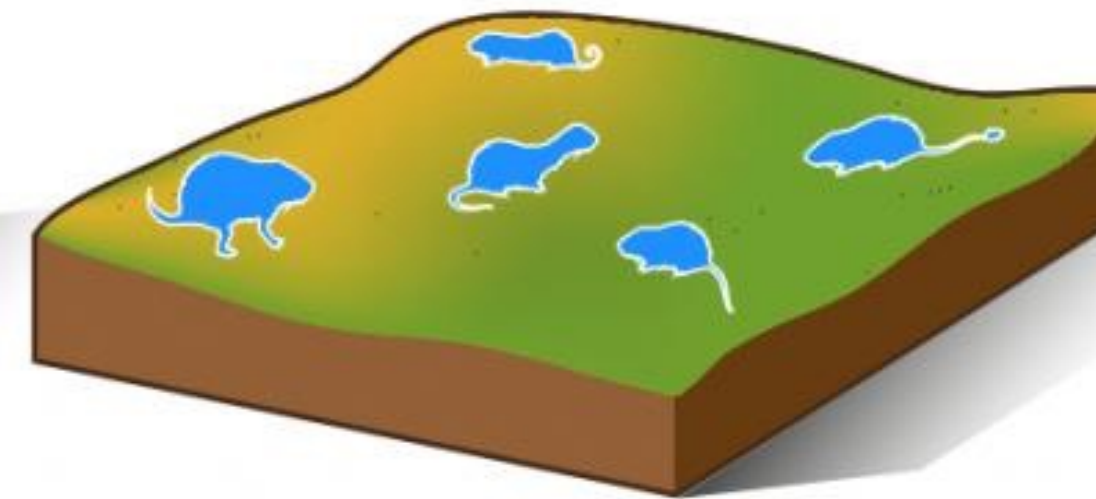
During the Ice Age, many large mammals roamed the earth, filling out deep branches on the mammal Tree of Life

## The Present

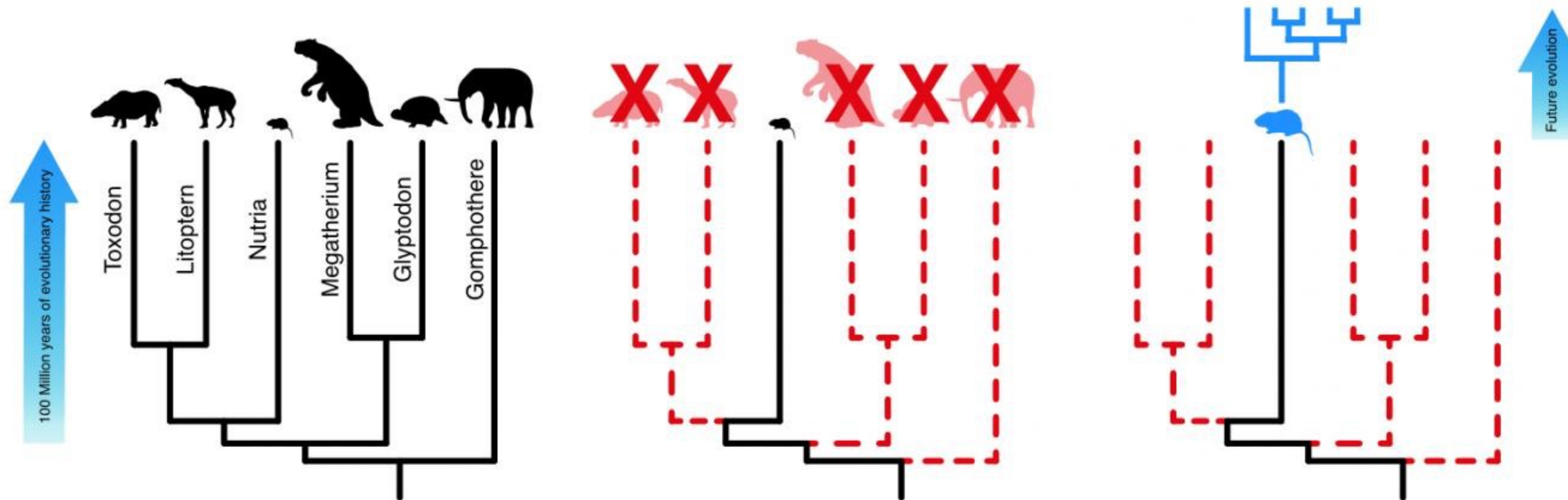


Since then, all the largest species have been chopped off the mammal Tree by extinctions

## The Future?



Surviving species will have to diversify for millions of years to restore this missing evolutionary history and regrow the Tree of Life





$$X = \frac{\delta E}{E} \left( 1 - \frac{U}{U + I} \right)$$

X: X-ness (extreme nature of the event)

E: ensemble

dE: Change/loss of ensemble

U: Unfolding time

I: Impact time



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Extinction of mammals:

E: all mammal species

dE: Species that go extinct

$$dE/E = 0.8$$

$$U = 300 \text{ years}$$

$$I = 5,000,000 \text{ years}$$

$$X = 0.79995 \sim 0.8$$

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Extinction of mammals has a very high X-ness



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1 How do the changes in global average surface temperature over the last five decades compare to previous variations in global surface temperature? In which region did the surface temperature change most?

Thoughts:



2 What are the three main drivers that determine Earth's climate and which of them have changed a lot during the last few decades? Describe the changes.

Thoughts:



3 The earth is currently storing on the order of 320 TW of additional energy. Where is this energy being stored and what are the potential impacts of this additional energy?

Thoughts:



4 What is the range of global average sea level change expected by 2100 and what contributes most to making this range large? What is the maximum sea level rise that we cannot safely exclude?

Thoughts: