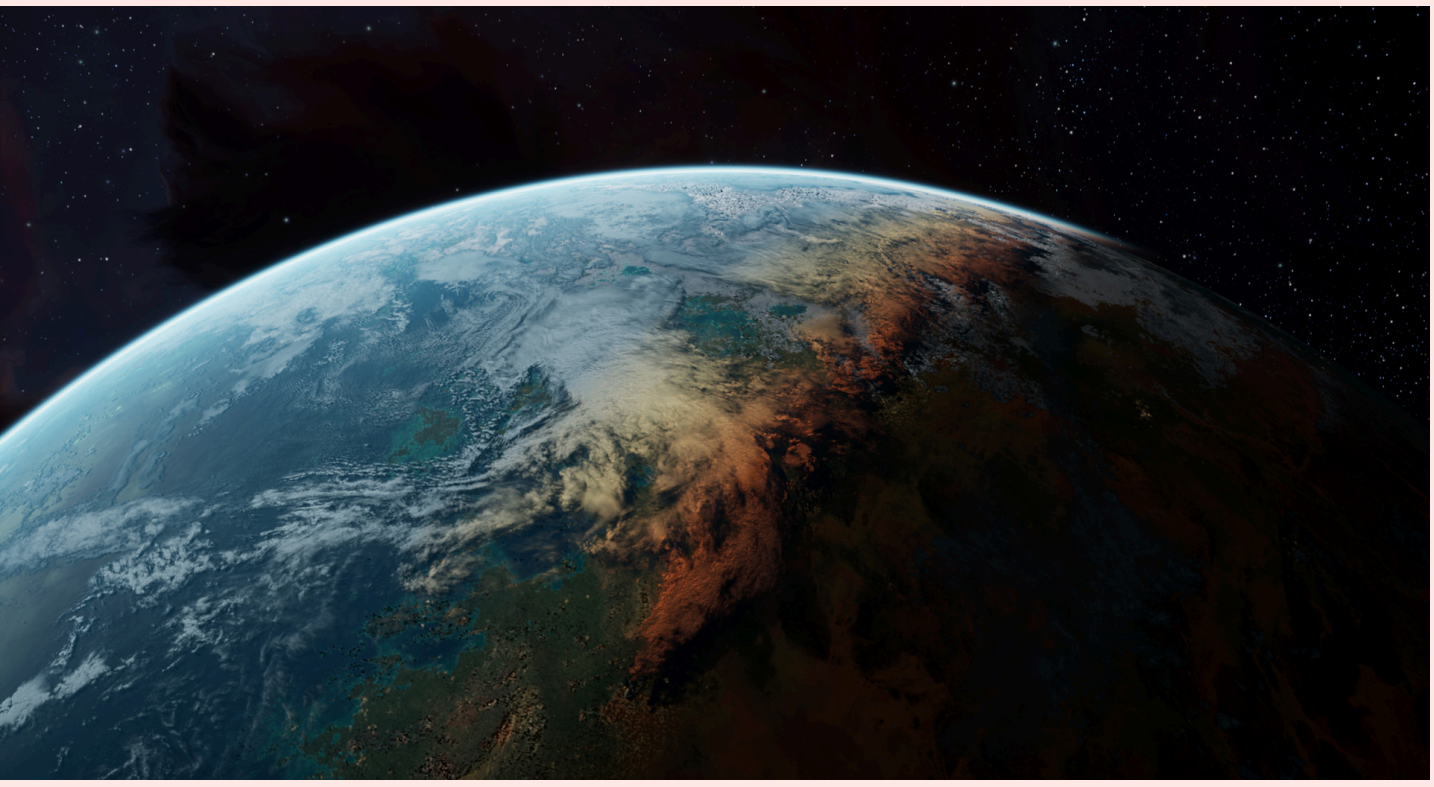
Empowering Youth through Environmental Storytelling

Planetary boundaries: climate change science



The boundaries of Earth being overstepped by human activity

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TEHRA
The Environment and Human Rights Academy

News Decoder

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The Empowering Youth through Environmental Storytelling is a collaboration between The Environment and Human Rights Academy (TEHRA), News Decoder and the Young Educators European Association (YEEA).

The purpose of these educational materials is to help young people understand the climate crisis on a systems level through engaging with the topics and foster agency through the skills and techniques of journalism.

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These educational resources have been developed to the best of our knowledge, using reliable and widely-recognized sources. While every effort has been made to ensure accuracy and clarity, we cannot guarantee that the materials are free from errors or omissions. Climate change is a field of knowledge that continues to evolve, and teachers and learners are encouraged to consult up-to-date scientific sources (e.g. IPCC, IPBES or national agencies) to complement and enrich these activities.

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European Association Young Educators

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Learning objectives

1. Understand how planetary boundaries represent human impacts on Earth's systems.
2. Find stakeholders and experts to contextualise complex information.

✅ GreenComp alignment:

- Systems thinking

Unit guide

We recommend that you begin your class with the Opening Activity, to have students visualise and imagine planetary boundaries. By discussing their feelings, thoughts, and confusions about the topic, you can already know what parts of the topic to focus more or less on.

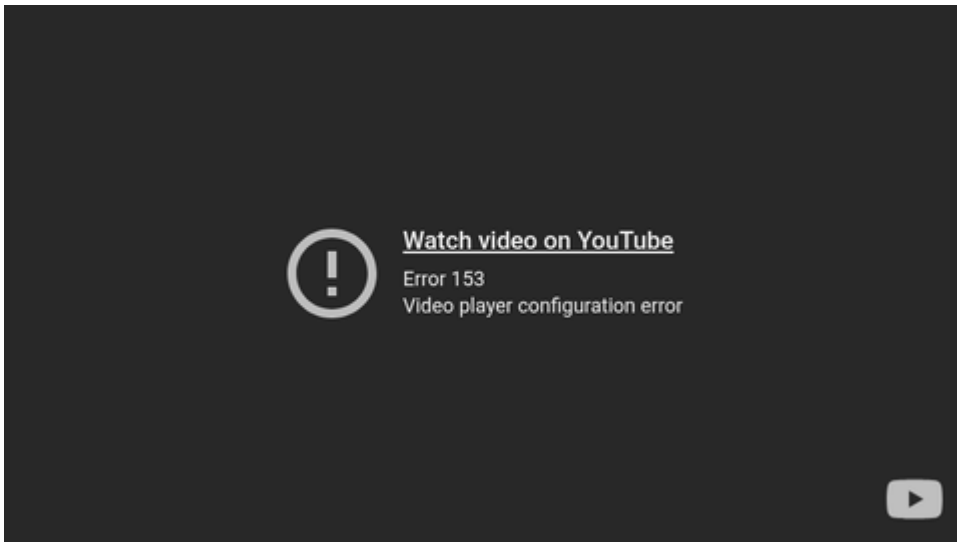
A Deeper Dive is provided on biodiversity should there be scope and interest.

The Project Instructions can be shown to students before or after going through the Learn section. For a more detailed guide on interviewing, please download the unit on Interviewing separately. It is up to you whether or not students conduct the interviews. There is already high value in conducting the research and finding some stakeholders and experts to speak with.

The link to the unit slides can be found here.

Watch and discuss

Watch this short video by Mongabay on planetary boundaries.



In the video, planetary boundaries are explained as:

"the limits of key Earth system processes that we cannot exceed if we want to avoid rapid and catastrophic environmental change"

Discuss:

1. How did this video make you feel?
2. What stuck with you?
3. Was there anything that was confusing or overwhelming?

1. What is a planetary boundary?

The science and mechanisms behind tipping points made us aware of the dangers of high levels of global warming.

To help understand how human actions directly affect various tipping elements, planetary boundaries combine the science of tipping points with indicators of human activity and its impacts.

Initially described by Johan Rockström and his team in 2009[1], the nine identified planetary boundaries were first fully quantified in 2023.[2]

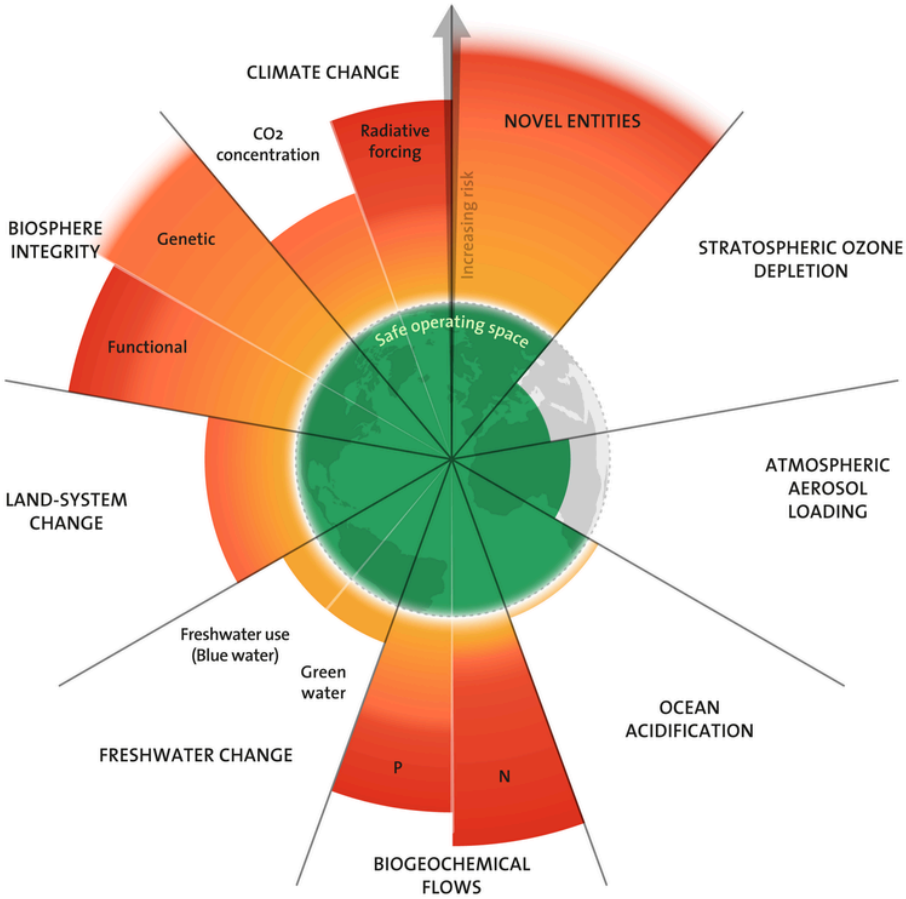


Figure 1: Graphic representation of nine planetary boundaries and how much human activities have impacted the systems they represent. Extent of the shading in each boundary's wedge reflects how strongly humans have impacted that system. The green space at the centre represents a 'safe operating space' within which impacts do not put the system at risk of collapse. Impacts beyond the planetary boundary / safe operating space put the system at increasing risk of collapse.[3]

The main, rather alarming, takeaway from the above figure is that of the nine identified planetary boundaries, human impact has pushed seven of these beyond their safe operating space and four in high risk zones.

These findings highlight the urgency and severity of the climate crisis. The impact of humans - and of certain countries, companies and groups in particular - on the functioning of Earth's systems is deep and widespread.

2. Planetary boundaries vs tipping points

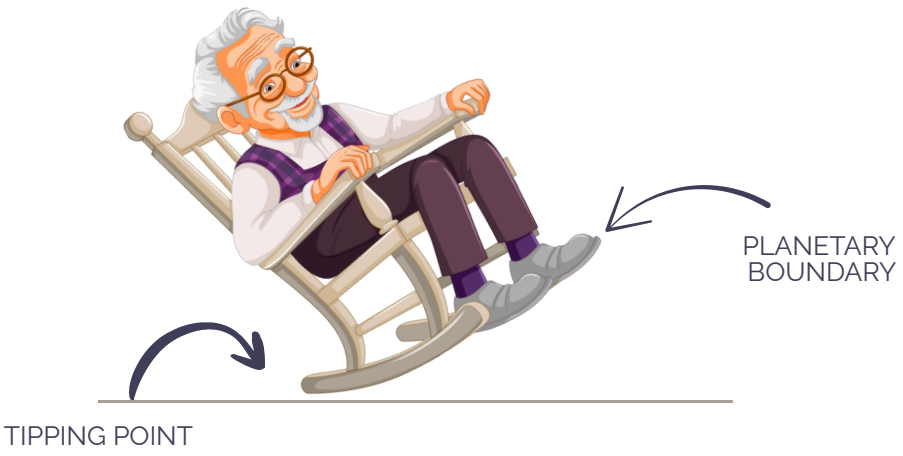
Transgressing a planetary boundary has similar implications to making a tipping element tip, with consequences involving catastrophic and largely irreversible change. There are however some important distinctions to be made between tipping points and planetary boundaries.

Tipping points describe how and when an Earth system might radically switch states.

Planetary boundaries describe how much human activities impact these systems and how close these systems subsequently might be to a radical change or collapse.

The tipping points framework is more process-focused, whilst planetary boundaries describe the current state of affairs.

We can carry over the rocking chair metaphor used in the tipping point unit to the concept of planetary boundaries too. The chair's tipping point describes when the chair will fall into its toppled over state. A planetary boundary for the chair would describe how strongly the pushing off with our legs increases the risk of it toppling over.



3. Individual planetary boundaries

The planetary boundaries shown in Figure 1 include climate change, novel entities, stratospheric ozone depletion, atmospheric aerosol loading, ocean acidification, biogeochemical flows, freshwater change, land system change and biosphere integrity.

We will quickly expand on each of those, explaining what the system is and if the boundary is crossed.

Possible activity: each group presents one boundary to the rest of the class.

Climate change:

In the Planetary Boundaries framework, climate change is measured by two indicators: radiative forcing (how much extra heat Earth traps and the amount of CO_2 in the atmosphere (ppm). The safe limits are 1 W/m^2 of extra heat[4]and 350 ppm of CO_2[5]. We have already gone far beyond the safe zone: by the start of this decade, radiative forcing was 2.39 W/m^2 and CO_2 levels 417 ppm.[6]

Novel entities:

Novel entities are defined as anything brought into and impacting Earth's system that is uniquely human. This includes materials such as microplastics and nuclear waste, but also processes such as genetic modification. It is clear that we have long overstepped this boundary. However, precisely measuring this kind of human impact is difficult, which is why the edge of the boundary in Figure 1 is blurred.

Stratospheric ozone depletion:

This boundary is specifically aimed at the gases emitted through human activities that erode the stratospheric ozone layer, a vital part of the atmosphere that controls harmful incoming solar radiation. Thanks to the Montreal Protocol of 1987 [7] levels of the ozone-eroding gases are now within safe limits. The Montreal Protocol is thereby a rare example of successful global political action to limit human impact on the environment to safe levels.

Atmospheric aerosol loading:

Aerosols are any small particles that are suspended in the atmosphere. Due to its wide definition, the impact of different sizes and types of aerosols is also very varied. In general, aerosols impact the climate by affecting incoming solar radiation and rainfall patterns. These impacts are both direct, but also indirect through aerosol's impact on cloud formation.

Ocean acidification:

Ocean acidification occurs as the ocean absorbs large amounts of CO2 emissions and severely impacts life in the oceans. This boundary has been crossed in 2025. Surface ocean pH fallen by around 0.1 units which is a 30-40% increase in acidity. This is severley impacting the functioning of marine ecosytems, especially dangerous for cold water corals, tropical coral reefs and Arctic marine life.[13]

Biogeochemical flows:

Nitrogen and phosphorus are elements vital to life. Mainly through intensive agriculture and fertilisation of crops, the natural nitrogen and phosphorus cycles have been severely altered. The ensuing effects include eutrophication events, when excess nitrogen and phosphorus runoff from fields end up in bodies of water. Here, they cause a boom in algae populations, which in turn starves the ecosystem of oxygen, leading to so-called 'dead zones', severely affecting biodiversity. This boundary is another which has been severely overstepped.

Freshwater change:

As seen in Figure 1, freshwater change is divided into blue and green water. Blue water is all surface and groundwater, whilst green water is water available to plants. Disruptions to the freshwater cycle impacts both of these and lead to changes in plant activity and thereby biodiversity, carbon sequestration and climate regulation. This boundary has also been crossed.

Land system change:

Land system change uses the three main forest biomes as reference points: boreal, temperate and tropical. Through extensive deforestation, land use change and wildfires, this boundary has already been transgressed, especially in the case of the Amazon rainforest (as discussed above).

Biosphere integrity:

The biosphere is integral to the functioning of human society, both by being a significant carbon source and thereby a key moderator of climate change, and by being a vital source of energy, food and resources. The ability of the world's biosphere to provide these 'services' is captured under the measure of 'functional' integrity. The ecosystems that make up the global biosphere are able to function as they do thanks to their biodiversity, represented by the measure of 'genetic' integrity. Both 'functional' and 'genetic' biosphere integrety has been severley disrupted.

Storytelling

Interview an expert

Do a quick search to find out how your country is performing in terms of the planetary boundaries. You can find an assessment of some planetary boundaries here, in a tool which can help you compare your country to other countries.

Which boundaries is your country contributing to crossing? Do some research to find out what industries are at the heart of your country's impact on planetary boundaries.

Who to interview

Make a short list of people you would want to interview about planetary boundaries in your country (or your continent).

Journalists use interviews to provide their story with meaning and significance. Through interviews, you can evoke emotion, put words on the greater impact of the issue you're exploring, and dive deeper into the significance of the data.

To find experts for your story, ask yourself the following questions:

- What kind of information do I need?
- Who would have real knowledge about that? Perhaps it would be someone who has written research papers in accredited journals, or someone who works in a particular industry, or maybe it's someone personally affected by the problem.

For example, if I want to find out more about planetary boundaries in Australia, I would do some research to soon discover that land use management is contributing to the crossing of multiple planetary boundaries.

If I wanted to find out more about why this is, and what's being done about it, I would interview:

1. The leading author on a report (Analyzing Australia's contribution to planetary health, Climateworks Centre) about the topic
2. An Indigenous ranger who is working to connect their knowledge and connection of land with policy in land protection
3. A public official working for Department of Lands in an Australian state, to find out their policy and strategy regarding planetary boundaries.

You can then go further by making a list of questions you would ask one or all of your sources, and maybe even conduct an interview!

The biodiversity planetary boundary

This chapter is suitable for classes that would like a closer look at climate change and biodiversity

Biodiversity, or biological diversity, is the variety of life on Earth. It spans at many levels- from genetic differences within species, to the variety of species and the ecosystems they form. It encompasses all living things, as small as microscopic organisms in the soil and as large as big mammals.

Nature is the totality of life on Earth, often understood through ecosystems which are composed of the species that make them, all of which are delicately interconnected into a biodiversity network. Many cultures also see humans as part of nature.

Biodiversity makes and helps nature thrive.

When thinking about biodiversity, humans and cultural diversity are sometimes included into biodiversity. This is called biocultural diversity. Humans and other species are inherently interlinked and influence each other. Our knowledge and beliefs shape our relationships with the living world, and the living world and ecological systems also influence us and how we behave. Biocultural diversity encompasses species, landscapes and the cultural links to spaces, as these connections play a big role in keeping our planet healthy.[8]

Biodiversity is an indispensable supporting factor for a healthy ecosystem. Ecosystems in turn are vital for humans by providing food, energy, materials, oxygen, and climate control. Nature is also a source of wellbeing for people.

However, biodiversity is declining across the globe at an alarming rate. The leading global body for biodiversity, IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services), released their latest Global Assessment in 2019.[9]

Here are some key findings of the report:

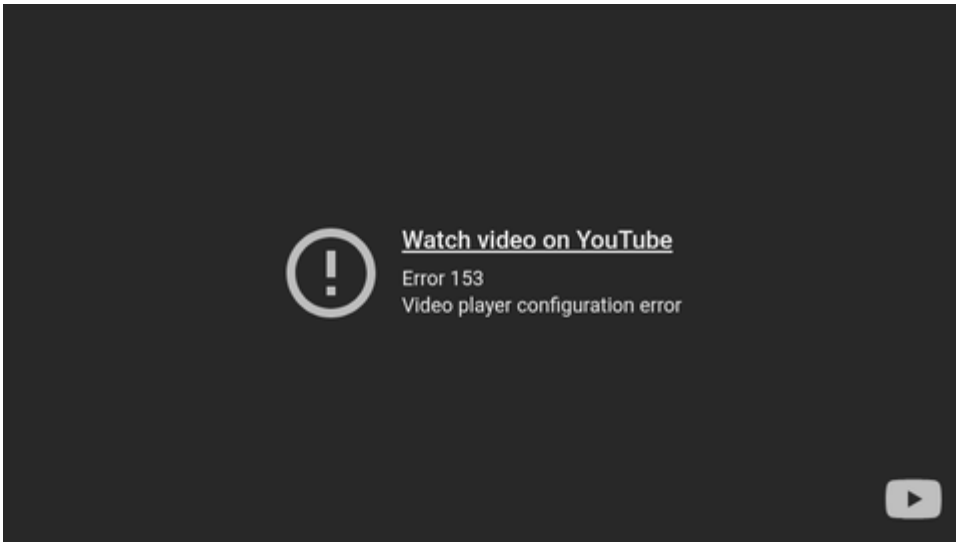
Modern day species extinctions are driven by human activities, both directly and indirectly. For instance, land use change, such as deforestation to free land for agricultural purposes, or building cities, and climatic changes directly lead to habitat degradation and destruction. Other threats to biodiversity include overexploitation and hunting, and the introduction of pollutants and toxins.[10]

Losses in biodiversity lead to ecosystem instability. You can think of an ecosystem as a choir or orchestra. Every species has a part to play: some loud and obvious, others quiet but essential for harmony. As voices or instruments disappear, the music becomes thinner, and eventually, the song can no longer be sustained. This is how an ecosystem can collapse with biodiversity loss.

This is why a more biodiverse ecosystem is also a more robust one. More species means that there is a higher chance that several species are doing the same job and so removing a species has less of an impact on the overall system. Also, different species are more resistant to different conditions. With declining biodiversity, ecosystems are becoming more unstable, increasing their risk of collapse due to the human factors listed above. Ecosystem instability also makes them and their species more vulnerable to disease and invasive species.[11]

Current extinction patterns are often labelled as the '6th mass extinction'. Current extinction rates[12] are up to a thousand of times higher than normal 'background' rates. An estimated 25% of all animal and plant species are threatened with extinction - a total number of around 1 million species. It is not only wild animals that are going extinct too - nearly 10% of all domesticated mammals have already gone extinct.

Ecosystems are vital for the survival of human societies. **Every part of our everyday lives is ultimately sustained by the ecosystems and the biological processes that underpin them.** Losing many of the world's species and ecosystems is not only disastrous for them, but also for humans.



Watch this video that shows how wolves change rivers. Discuss your thoughts.

Not all species contribute to ecosystem stability equally. There are so-called 'keystone species' whose loss can have many cascading effects on ecosystems.

Wolves, for example, are keystone species. If they get extinct from a certain area, or their population drastically reduces, there won't be other species to replace their function of eating and so controlling the population of herbivores, such as deer.

When there are too many deer, they eat too many plants and young trees — a problem called overgrazing. This harms other animals that depend on the plants, and can even change the landscape, soil, and rivers over time.

Endnotes

1. Rockström et al. (2009): A safe operating space for humanity. Available at: https://www.nature.com/articles/461472a

2. Richardson et al. (2023): Earth beyond six of nine boundaries. https://www.science.org/doi/10.1126/sciadv.adh2458

3. Ibid.

4. Radiative forcing measures how much additional heat energy (Watts, W) is trapped per square metre (m^2) of atmosphere due to anthropogenic greenhouse gases. Radiative forcing is therefore measured in Watts per square metre (W/m^2).

5. Richardson et al. (2023): Earth beyond six of nine boundaries. Available at: https://www.science.org/doi/10.1126/sciadv.adh2458

6. Intergovernmental Panel on Climate Change (2021): Climate Change 2021: The Physical Science Basis

7. More details about the Montreal Protocol can be found at https://www.unep.org/ozonaction/who-we-are/about-montreal-protocol

8. American Museum of Natural History (n.d.) What is Biodiversity? https://www.amnh.org/research/center-for-biodiversity-conservation/what-is-biodiversity

9. Information about the Global Assessment, the summary document and full document can be found at https://www.ipbes.net/global-assessment

10.IPBES (2019): Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services

11. Following the previous five which have occurred in the deep past between 66 and 444 million years ago, including famously the dinosaurs' Cretaceous–Paleogene extinction event 66 million years ago.

12. De Vos et al. (2014): Estimating the normal background rate of species extinction

13. Planetary Boundaries Science (PBScience). (2025): Planetary Health Check 2025. Potsdam Institute for Climate Impact Research (PIK), Potsdam, Germany. https://publications.pik-potsdam.de/rest/items/item_32589/component/file_33044/content

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