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Editorial: Surviving the Anthropocene: the 3 E's under pressing planetary issues

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Editorial on the Research Topic
Surviving the Anthropocene: the 3 E's under pressing planetary issues

In 1983, Stephen J. Gould asked, "Has any other species ever left so many visible signs of its relentless presence?" (Gould, 1983). At that time, planet Earth had approximately 4.7 billion human inhabitants[1]. 42 years later, the human population has surpassed the 8 billion mark, and Gould's question could not be more fitting to the Anthropocene. The term "Anthropocene" was coined 25 years ago by the late atmospheric chemist and Nobel Laureate Paul Crutzen (Crutzen and Stoermer, 2000). After studying the formation (and destruction) of Earth's ozone layer, Crutzen realized we had entered a new human-driven epoch (Crutzen, 2002). "Anthropocene" soon became popular among academics (particularly social scientists) and media. Despite widespread acceptance of the term, clear stratigraphic data were needed to determine if, indeed, we entered a new geological epoch. Consequently, the Anthropocene Working Group[2] (AWG) was formed under the Subcommission on Quaternary Stratigraphy (SQS). Its goal was to find the Global Boundary Stratotype and Point (GSSP; golden spike in lay terms) that delimits the beginning of the Anthropocene. After 16 years of meticulous and strenuous work, the group proposed Crawford Lake, a meromictic lake in Southern Ontario, as the top candidate to contain the clearest Anthropocenic GSSP (McCarthy et al., 2023). In a somewhat controversial move, the SQS tabled the AWG proposal and determined that we are still in the Holocene[3].

Scientists, including stratigraphists, all agree that our species has changed planet Earth in unprecedented ways. But contention exists around the actual start date and the diachronicity of the global human impact (Boivin et al., 2024). Indeed, the term "Anthropocene" is not the

first attempt to name the consequences of human activities on our planet (Steffen et al., 2011), and several starting dates for the Anthropocene (from the emergence of the human species to the Great Acceleration and nuclear tests) have been eloquently defended (Logan, 2022). Furthermore, given the social and monetary aspects of the Anthropocene, terms like Capitalocene have been proposed as well (Moore, 2016). As highlighted in this Research Topic, López-Corona and Magallanes-Guijón introduce the concept of Technocene and explain why human technology must take a central place in the definition of our current period. Interestingly, the existence of so many terms trying to explain our impact on Earth could already be an indicator that we are, in fact, in a moment at which human interference is changing Earth's natural history.

Humans are a hyperkeystone species (Worm and Paine, 2016) that are now considered the "world's greatest evolutionary force" (Palumbi, 2001), and biologists have been studying how the 3 E's (Ecology, Ethology, and Evolution of species) unfold in our challenging times (West et al., 2025). Concepts such as plasticity, evolvability, niche construction, evolutionary traps, and extinction vortex abound in the Anthropocenic Biology literature. Evolutionary biologists, thus, have a fundamental role to play in the progression of our current geological epoch. Arguably, the Anthropocene is a global evolutionary experiment in itself. Adaptive and non-adaptive mechanisms of evolution (*e.g.*, mutation, recombination, genetic drift, and selection) are now under strong human influence. Cities, which boast more than 50% of the 8 billion people on Earth[4], are insurmountable sources of chemicals that can alter mutation rates in urban ecosystems (Johnson et al., 2024). Waste treatment stations are hotbeds for the spread of antibiotic-resistance genes via horizontal gene transfer among bacteria (Bradshaw, 2024). Land-use change, both in rural areas and in city borders, cause fragmentation of natural habitats and increase the chances of (detrimental) genetic drift (Nordstrom et al., 2023). Anthropogenic pressures, both local and global, can alter patterns of natural and sexual selection (Boughman et al., 2024). The spread of exotic species by humans (intentionally or not) has created the conditions for countless hybridization events with potential detrimental consequences for the affected species (Ottenburghs, 2021). Evolvability (Urban et al., 2024), biological agency (Okasha, 2024), and niche construction (Wade and Sultan, 2023) are processes that also seem to be ever more salient in the Anthropocenic world. Pointedly, one of the most pressing challenges for evolutionary studies in the Anthropocene is differentiating evolutionary (heritable) change from phenotypic plasticity (Sanita Lima et al., 2024). Whether phenotypic plasticity is adaptive or not and whether plasticity itself evolves has also been under intense scientific scrutiny recently (Arnold et al., 2019; Fox et al., 2019).

In other words, the tempo and mode of evolution in the Anthropocene are changing (Otto, 2018). Concepts like contemporary evolution (Stockwell et al., 2003), human-induced evolution (Baltazar-Soares et al., 2021), and rapid evolution (*i.e.*, evolution on ecological timescale) (Carroll et al., 2007) are now under sharp(er) focus. The signatures of the Anthropocenic world – chemical, visual, and acoustic pollution in land, water, and air – create pervasive evolutionary traps (Robertson et al., 2013) and increase the chances of maladaptation for both humans and non-human species (Crespi, 2000). The defaunation of the Anthropocene (Dirzo et al., 2014) is just one component of our extinction debt (Tilman et al., 1994), and as we change our world in unfathomable ways, we further impede evolutionary rescue by creating the conditions for extinction vortexes (Carlson et al., 2014; Nordstrom et al., 2023). Therefore, documenting and assessing our natural environments are of utter importance now. Morgan-Kiss et al. and Cristine da Silva et al. provide examples of how long-term and paelo-ecological field studies can be used for the monitoring of biodiversity in the Anthropocene.

At least 140 countries have vowed to reach NetZero by 2050 (or 2060 in some cases)[5]. Such a goal is honorable and deserves our all-hands-on-deck commitment. However, governments are betting on their NetZero targets for carbon-capture technologies, which are not yet effective on a large scale (Ma et al., 2022), while billionaires commission private flights to space[6] and/or sell risky/ill-thought-out promises of colonizing/terraforming Mars (Levchenko et al., 2019). Climate geoengineering – the capture of atmospheric carbon and/or the alteration of solar radiation on Earth – lurks around ever chillingly (Schäfer and Low, 2014), while we continue business as usual. Amidst the inertia and grim prospects, it is easy to resort to climate nihilism (Greta, 2023), but we need to continue devoting our ingenuity for the cause. For instance, Brothers and McCarthy propose the "Anthropocene meal" and explain how urbanized societies can contribute to a more sustainable Anthropocenic world. Evolutionary biologists are also proposing to inform policy and prescribe ways to mitigate our impact on the planet (Smith et al., 2014; Jørgensen et al., 2019).

But as biologists tell these (unsettling) tales of the Anthropocene, they should also think about a world after the Anthropocene (Watson and Watson, 2020). Despite the havoc we wreak in our planet, life will likely not cease to exist in the near (geological) future. Wildlife has returned in astonishing numbers both in Chernobyl (Deryabina et al., 2015) and the Bikini Atoll (Richards et al., 2008), places that were once decimated by nuclear radiation. That life continues to persist after these events and other mass extinctions shows that evolution is powerful, and life is resilient. One day, paleontologists of the future will be certain that the Holocene no longer existed by the turn of the 21st

1 https://www.worldometers.info/world-population/world-population-by-year/

2 https://quaternary.stratigraphy.org/working-groups/anthropocene

3 https://www.nytimes.com/2024/03/05/climate/anthropocene-epoch-vote-rejected.html

4 https://ourworldindata.org/urbanization

5 https://www.un.org/en/climatechange/net-zero-coalition

6 https://www.theguardian.com/science/2021/jul/19/billionaires-space-tourism-environment-emissions

century. They will see a period marked by accelerated evolution, mass extinction, and homogenized biodiversity. It is on us then to determine what the post-Anthropocene will look like, and we should not forget that we have just one shot.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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