Studying pauses and pulses in human mobility and their environmental impacts

Christian Rutz

Human mobility was drastically reduced during COVID-19 lockdowns, and could surge beyond pre-pandemic levels as restrictions ease. A classification scheme enables robust comparative analyses of pauses and pulses in human mobility — from anthropauses to anthropulses — providing invaluable insights into anthropogenic environmental impacts.

In June 2020, my colleagues and I introduced the term 'anthropause', to describe the substantial reduction in human mobility observed during early COVID-19 lockdowns[1]. The word has struck a chord, garnering widespread attention amongst scientists, scholars, artists, journalists, and the general public. Meanwhile, our article's scientific proposition — namely, to use the COVID-19 anthropause to investigate humans' impact on the environment (FIG. 1a) — is being pursued productively around the globe, affording fresh perspectives for conservation biology and environmental planning[2,3]. The research community is working hard to make a positive contribution during this devastating crisis.

Early COVID-19 lockdowns caused an extraordinary shock to the Earth system[1,4], but there have been other major pauses in human mobility, at local, regional and even continental scales[5,6]. Examples include the nuclear exclusion zones in Chernobyl, Ukraine and Belarus, and Fukushima, Japan, the Korean demilitarized zone, and the 14th century Black Death pandemic in Eurasia and North Africa[5]. Comparing pauses in human mobility across scales and contexts promises invaluable mechanistic insights into human–environment interactions[1], but requires a robust conceptual framework and terminology.

Here, I introduce a multi-dimensional classification scheme for pauses in human mobility that enables refinement of the anthropause definition, prompts the introduction of the complementary 'anthropulse' concept, and helps identify research priorities in this fast-moving field.

A classification scheme

I propose a basic classification scheme for human pauses based on how widespread (spatial extent), sustained (duration) and pronounced (magnitude) reductions in human mobility are (FIG. 1b). Importantly, I recommend that the label anthropause be reserved for events of high magnitude at continental to global scale (and of any duration; FIG. 1b, Supplementary Note 1). According to this definition, the Black Death pandemic and early COVID-19 lockdowns caused anthropauses, while the Chernobyl disaster was followed by a regional human pause. A schematic classification cube can be used to compare these and other events (FIG. 1b); but first, a few points need clarifying.

First, it is crucial to ensure that terminology is firmly tied to underlying processes. Some authors have used the word anthropause as a synonym for positive environmental change caused by lockdowns. While an initial focus on potential benefits is understandable, conflating cause (change in human mobility) and effect (environmental responses) is unhelpful when using the term in a scientific context. Indeed, the way the anthropause concept was originally framed, it makes no assumptions about the sign of environmental responses and any associated conservation impacts[1] (FIG. 1a). Emerging empirical evidence from the COVID-19 pandemic indicates a broad range of lockdown effects[2,3].

Second, human mobility must be defined. COVID-19 lockdowns caused notable reductions in pedestrian counts and road, water and air traffic (and associated pollutant outputs), all of which likely caused environmental impacts[1–4]. For modern human pauses, it is reasonable to consider changes across the full range of human-mobility metrics, but comparisons with pre-industrial events inevitably need to focus on the environmental presence of people. In this context it is worth noting that humans might disappear from an area because they shelter, move elsewhere or perish, and that changes in human mobility can be driven by a variety of factors, including disease, natural and anthropogenic disasters, and conflict[5]. The ultimate drivers and proximate mechanisms affecting changes in human mobility are important research targets, but not part of the classification scheme itself (FIG. 1b). It is important to be mindful of the fact that many events will be associated with human tragedy and suffering[1].

Centre for Biological Diversity, School of Biology, University of St Andrews, St Andrews, UK.

e-mail: christian.rutz@st-andrews.ac.uk

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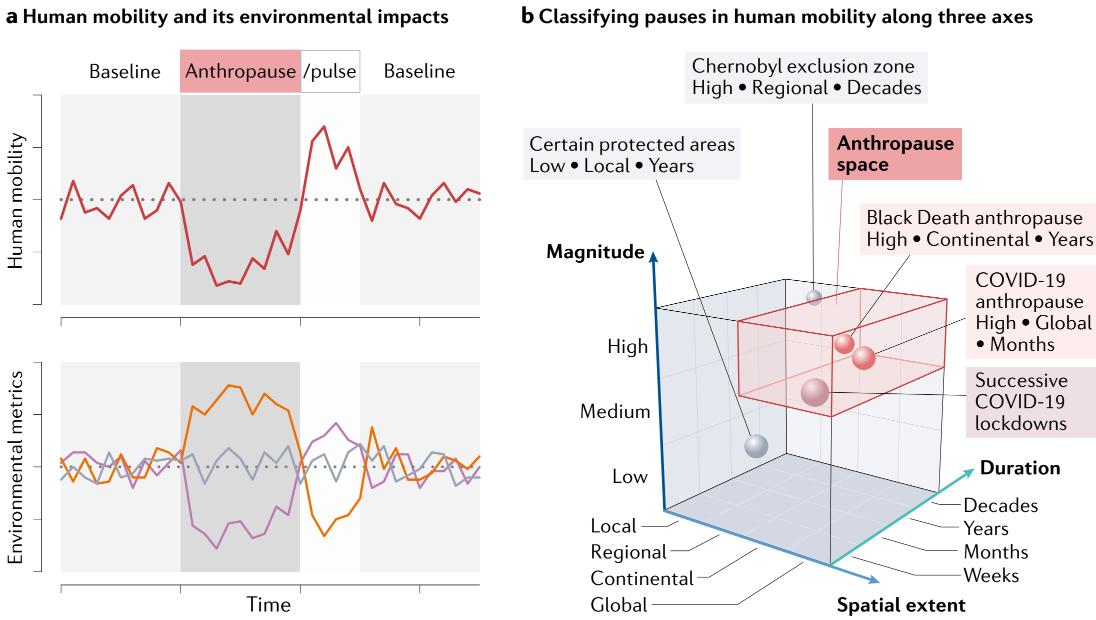

Fig. 1 | **Studying pauses and pulses in human mobility. a** | An anthropause is an unusual, substantial, temporary, continental- to global-scale reduction in human mobility (top), which can cause a variety of environmental responses (bottom), with beneficial, adverse or no conservation impacts (conceptual diagram). An anthropulse is the reverse phenomenon that might directly follow an anthropause. **b** | A classification scheme places human pauses along three main axes: magnitude (that is, reduction in human mobility relative to contemporary baseline levels); spatial extent (the four categories depicted here correspond tentatively to areas spanning approximately 10s, 100s, 1,000s and 10,000s of kilometres); and duration. Early COVID-19 lockdowns and the Black Death pandemic can be classed as anthropauses as they were events of high magnitude at global and continental scales, respectively (red balls); it remains to be determined, however, if subsequent COVID-19 lockdowns (greyish-red ball) of relatively reduced magnitude, spatial extent and duration also fall within the anthropause space. Placement of events in this conceptual diagram is indicative only, and resolving the magnitude scale quantitatively will require empirical benchmarking. An analogous scheme can be used to classify human pulses, including anthropulses.

Third, operational definitions are required for the scheme's spatio-temporal scales. While human pauses are easily ordered according to their duration, classifying their spatial extent is more challenging, for both conceptual and practical reasons[7]. The categories proposed here are pragmatic — spanning four orders of magnitude (FIG. 1b) — and will enable meaningful comparison of the environmental impacts caused by different types of human pauses.

Finally, it is important to clarify how the magnitude of events should be measured. Since human mobility dramatically increased over the past centuries, and will likely change further in the future, the magnitude of human pauses should be assessed against baseline levels for the time period and area under consideration, rather than in absolute terms. As illustrated by the COVID-19 pandemic, human mobility is not necessarily reduced to zero during an anthropause, and there can be substantial spatio-temporal variation in response levels. Preliminary analyses indicate that ~57% of the world's population were under partial or full lockdown in early April 2020[2], and there were conspicuous local spikes in mobility once governments started allowing personal exercise[1].

Introducing the anthropulse concept

As governments ease COVID-19 restrictions, recreational and other activities could surge beyond pre-pandemic baseline levels. If a pulse in human mobility is sufficiently pronounced — in terms of magnitude and spatial extent — I suggest it be referred to as an 'anthropulse', using a definition analogous to that proposed above for anthropause. Indeed, the classification scheme for human pauses easily accommodates human pulses, with magnitude measuring increases in human mobility compared to baseline levels, rather than decreases.

While COVID-19-related pulses in human mobility would likely cause substantial environmental damage, the (partial) temporary reversal of lockdown conditions would enable powerful tests of causality. In some contexts, if a certain environmental response was observed during the anthropause (say, a positive effect), detecting a response in the opposite direction (negative effect) during a subsequent human pulse could strengthen inferences about mechanistic links (FIG. 1a). Such a semi-experimental reversal of conditions is rarely achievable in environmental impact studies[8], but could occur across many sites as the pandemic wanes.

According to my terminology, an anthropause can co-occur with localized, smaller human pulses, and eventually cease by disintegrating into smaller human pauses, as indeed observed during the COVID-19 pandemic (FIG. 1b).

Research needs and opportunities

The above classification scheme brings into focus how pauses and pulses in human mobility can be used to investigate human–environment interactions, and it helps identify several research priorities.

First, charting the detailed anatomy of the COVID-19 anthropause is key for empirical benchmarking. While valuable first analyses have been conducted using selected mobility metrics[2,4], it is now important to validate proxies, improve spatial coverage, and integrate information globally. Pinpointing the start and end of the COVID-19 anthropause presents particular challenges, not least because of marked spatio-temporal variation in restriction regimes, compliance levels and human behaviour, during successive waves of lockdowns (FIG. 1b). My colleagues and I from the COVID-19 Bio-Logging Initiative, which analyses global animal tracking data collected during the pandemic[1], have started tackling these objectives.

Second, as restrictions are being lifted, researchers should urgently prepare to document imminent human pulses and their potential environmental impacts, to complement analyses of the COVID-19 anthropause. Spikes in human mobility seem likely, as people attempt to 'make up' for missed work and recreational travel in 2020–2021, but it remains to be seen if the situation will escalate into a full-scale anthropulse.

Third, while most attention is currently focussed on mapping immediate lockdown effects, it is essential to examine possible long-term consequences. For example, in some animal species and environmental contexts, sudden lockdown-related changes in movement and foraging behaviour could occur, which later impact reproductive and mortality rates, and ultimately translate into altered population levels and distributions[9]. Likewise, lockdowns can trigger complex cascading effects that take time to manifest[2,4].

Finally, since future diseases and other major perturbations seem inevitable, research networks and other stakeholders should urgently work towards achieving some form of 'anthropause preparedness'. During the first lockdown period, many field workers were unable to continue data collection, and entire research communities scrambled to launch consortia to coordinate time-sensitive collaborative work[1–3,9]. Investments should now be made into the development of innovative, fully-autonomous data-collection systems, more inclusive and resilient collaborations with local communities, and robust infrastructure and workflows for rapidly sharing and harmonizing complex datasets. The global animal tracking community has started addressing these ambitious goals[1,10].

Driving positive change

I have focussed here on the scientific use of the anthropause concept, explaining how it can guide investigations of environmental responses to COVID-19 lockdowns[1–4,9] and inspire broader comparative analyses across human pauses[5] and pulses. But the concept transcends disciplinary boundaries and forces us to evaluate more generally humanity's impact on, and relationship with nature.

As the world emerges from the tragic circumstances of the COVID-19 pandemic, our improved understanding of human–environment interactions must be used to plan for a more sustainable future.

1. Rutz, C. et al. COVID-19 lockdown allows researchers to quantify the effects of human activity on wildlife. *Nat. Ecol. Evol.* **4**, 1156–1159 (2020).
2. Bates, A. E. et al. Global COVID-19 lockdown highlights humans as both threats and custodians of the environment. *Biol. Conserv.* **260**, 109175 (2021).
3. Schrimpf, M. B. et al. Reduced human activity during COVID-19 alters avian land use across North America. *Sci. Adv.* **7**, eabf507 (2021).
4. Diffenbaugh, N. S. et al. The COVID-19 lockdowns: a window into the Earth System. *Nat. Rev. Earth Environ.* **1**, 470–481 (2020).
5. Searle, A., Turnbull, J. & Lorimer, J. After the anthropause: lockdown lessons for more-than-human geographies. *Geogr. J.* **187**, 69–77 (2021).
6. Flyn, C. *Islands of Abandonment: Life in the Post-Human Landscape* (William Collins, 2021).
7. Herod, A. *Scale* (Routledge, 2010).
8. Wauchope, H. S. et al. Evaluating impact using time-series data. *Trends Ecol. Evol.* **36**, 196–205 (2021).
9. Sumasgutner, P. et al. Raptor research during the COVID-19 pandemic provides invaluable opportunities for conservation biology. *Biol. Conserv.* **260**, 109149 (2021).
10. Jetz, W. et al. Biological Earth observation with animal sensors. *Trends Ecol. Evol*. (in the press).

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Competing interests
The author declares no competing interests.

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