PLOS SUSTAINABILITY AND TRANSFORMATION

REVIEW

Social–ecological systems approaches are essential for understanding and responding to the complex impacts of COVID-19 on people and the environment

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Abstract

The Coronavirus Disease 2019 (COVID-19) pandemic is dramatically impacting planetary and human societal systems that are inseparably linked. Zoonotic diseases like COVID-19 expose how human well-being is inextricably interconnected with the environment and to other converging (human driven) social–ecological crises, such as the dramatic losses of biodiversity, land use change, and climate change. We argue that COVID-19 is itself a social–ecological crisis, but responses so far have not been inclusive of ecological resiliency, in part because the "Anthropause" metaphor has created an unrealistic sense of comfort that excuses inaction. Anthropause narratives belie the fact that resource extraction has continued during the pandemic and that business-as-usual continues to cause widespread ecosystem degradation that requires immediate policy attention. In some cases, COVID-19 policy measures further contributed to the problem such as reducing environmental taxes or regulatory enforcement. While some social–ecological systems (SES) are experiencing reduced impacts, others are experiencing what we term an "Anthrocrush," with more visitors and intensified use. The varied causes and impacts of the pandemic can be better understood with a social–ecological lens. Social–ecological insights are necessary to plan and build the resilience needed to tackle the pandemic and future social–ecological crises. If we as a society are serious about building back better from the pandemic, we must embrace a set of research and policy responses informed by SES thinking.

1. Introduction

In 2019, a landmark global assessment by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) warned that 1 million species were at risk of

extinction [1,2]. In 2020, the international community failed to achieve a single biodiversity target to stop the destruction of nature [3]. Now in 2022, we are entering the third year of a global human pandemic linked to this biodiversity crisis, caused by an infectious disease that presumably originated from a spillover event from natural wildlife reservoirs into the human population.

The Coronavirus Disease 2019 (COVID-19) pandemic (hereafter, "the pandemic") is dramatically impacting planetary systems [4]. The rapid spread of COVID-19 to nearly every human-inhabited territory on the Earth has massive (potentially permanent) impacts on the global community—on people's lives and health, livelihoods, and behaviors—leading to mortality, upheaval, suffering, isolation, and vulnerability. In addition to causing illness and death, the pandemic and associated public health measures, such as physical distancing and lockdowns, have impacted mental health and well-being (e.g., anxiety, fatigue, stress, substance use, and trauma) [5–7]. Other personal disruptions include job losses, food insecurity, delays in medical care, and disturbances in supply chains. These impacts have been felt at all scales of society (individuals, families, communities, institutions, and nations) in both urban and rural areas and in higher-income and lower-income countries. Beyond these consequences on human society, we must also attend to consequences of the pandemic on the biophysical environment that is inseparably linked to human well-being. In the field of environmental science, the pandemic and associated global lockdowns have been framed as an unplanned "Global Human Confinement Experiment" [8]. To help researchers reveal the impacts of human society on biophysical environments, Rutz and colleagues [9] termed the period of unusually reduced human activity and mobility due to COVID-19 restrictions as the "Anthropause."

Social–ecological systems (SES) conceptualize how social "human systems" (e.g., individuals, communities, and institutions) and ecological "natural systems" (e.g., ecosystems, biodiversity, and climate) are explicitly and inherently interlinked through bidirectional relationships. We suggest that the SES concept is essential for understanding and responding to the complex impacts of COVID-19. Interpreting COVID-19 (and other human–nature crises like the biodiversity crisis [10]) through an SES lens is essential for a variety of practical reasons: Integrated studies of coupled human and natural systems reveal new and complex patterns and processes like nonlinear dynamics, feedback loops, tipping points, and time lags not evident when studied by social or natural scientists separately [11,12]. For example, pandemic-related impacts can be felt immediately (onset of the pandemic) or in the short medium (in the first year) or long term. These patterns and processes again become apparent only when the full SES is taken as the unit of analysis and doing so can inform more holistic—and effective—policy responses. SES can support integrated analysis of the pandemic, recognizing (1) the need for collaborations across professional, cultural, geographic and disciplinary backgrounds to address complex problems; (2) that systems exist and function at multiple scales of time, space, and social organization; and (3) that social–environmental effects interact and accumulate over space and time and do not respect jurisdictional or temporal boundaries. SES can also act as a boundary object that provides a common language and terminology that can be adapted to different disciplinary or professional contexts, thus enabling collaboration across the natural and social sciences when tackling complex issues, such as COVID-19 [13].

An important aspect of SES thinking is resilience [14] or the capacity of an SES to absorb or withstand perturbations and other stressors. Resilience generally refers to the capacity of people, society, or systems to adapt to change and adversity. In essence, resilience is the ability to recover and decrease vulnerability to future crises. While we have faced many individual and collective traumas during the COVID-19 pandemic, practices such as self-care and staying connected to our loved ones online during lockdowns have helped us adapt, grow, and be resilient in the face of difficult circumstances. The same idea applies to nature: Ecological resilience

is the capacity of nature to absorb or withstand disturbance and stress while maintaining its structure and functions. For example, in agricultural ecosystems producing pollinator-dependent fruiting crops, those that rely on a single pollinator like the honeybee are more likely to be affected by colony collapse disorder, a phenomenon that occurs when the majority of worker bees in a colony disappear [15]. Conversely, an agroecosystem is more likely to be resilient to disease when it supports a large diversity of pollinators [16]. Social–ecological resilience embodies the capacity of linked SES to absorb recurrent disturbances to retain essential structures, processes, and relationships [17].

In many ways, COVID-19 can be viewed as a disturbance that transcends the presumed boundaries of human and environmental systems. Unanticipated outcomes and ongoing feedback loops of the pandemic will require proactive and comprehensive research and actions to address negative impacts. If we as a society are serious about building back better from the pandemic, our efforts will need to be comprehensive, ambitious, and inclusive of social–ecological resilience. Through this lens, COVID-19 can be conceptualized as a social–ecological crisis: Interlinkages between ecological and social systems reveal that the increasing magnitude and rate of negative impacts to human well-being and welfare (such as those caused by the pandemic) are inextricably associated with the rapid loss of biodiversity and the rapid degradation of ecosystems that support human societies [18].

Building on the concepts of SES and resilience, we put forward several core arguments that serve as a roadmap for this review:

1. COVID-19 is a social–ecological crisis, but responses so far have not been inclusive of ecological resiliency, in part because the "Anthropause" metaphor has created an unrealistic sense of comfort about the state of nature that excuses inaction.
2. The pandemic has had tangible negative impacts on SES.
3. The causes and impacts of the pandemic can be better understood with an SES lens.
4. Social–ecological resilience is needed to tackle the pandemic and future social–ecological crises.
5. We must embrace an SES-informed set of research and policy responses.

1.1. COVID-19 is a social–ecological crisis

We contend that the pandemic is a social–ecological crisis, highlighting our increasingly connected, simplified, and intensified global production ecosystem [19] and humanity's perverse relationship with the environment and biodiversity [20]. Most zoonotic (i.e., animal borne or transmitted) disease pandemics develop from the unsustainable exploitation of nature [21] and indeed, signs point to COVID-19 being a "scourge caused by our dismissive regard for nature" [22]. In 2016, the United Nations Environment Programme (UNEP) found a global increase in zoonotic epidemics, with the origins of 75% of emerging infectious diseases identified as closely linked with environmental changes [23]. Zoonotic diseases like COVID-19 expose how human well-being is inextricably interconnected with the environment and other converging (human driven) social–ecological crises, such as the dramatic losses of biodiversity, land use change, and climate change (Fig 1). All of these are social–ecological crises that involve people and the environment. For example, findings from a 2019 global assessment by IPBES can be interpreted through an SES lens, as they found that biodiversity loss reduces the capacity of nature to regulate the human body's immune system function and mitigate disease outbreak and spread, underscoring the central and foundational role of biodiversity in

Fig 1. Inextricably interconnected social–ecological crises. Top then bottom (from left to right): biodiversity loss, land use change, climate change, COVID-19 pandemic. COVID-19, Coronavirus Disease 2019. *Image sources*: *zanskar*, *ollo*, *izanbar*, *and Gargonia via iStock (standard license)*.

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regulating human and ecological health [1,2]. It is becoming increasingly apparent that emerging zoonotic infectious disease can be exacerbated by human activities such as land clearing and habitat fragmentation, further demonstrating the link between human well-being and the environment [1,2,24,25]. What's more, vector-borne pathogens that infect humans, livestock, and wildlife are expected to spread more rapidly and more often with climate change-induced warming [26] and environmental degradation [24]. Taken individually or together, these crises threaten global security by undermining the resilience of SES. "They [major social-ecological crises] are all interrelated, with many of the same causes and solutions," as noted by Cristián Samper of the Wildlife Conservation Society to the One Planet Summit of global leaders in Paris in January 2021 [22]. An SES lens is critical for moving away from the treatment of nature as something that can be exploited and degraded, to recognizing nature as an integral partner to life on Earth.

1.2. Current responses to the pandemic do not account for social–ecological complexity

Despite some recognition of the need to address COVID-19 as a social–ecological crisis (e.g., [27,28]), most pandemic response efforts have focused exclusively on human resilience and investing new money into old structures. For example, many higher-income countries (e.g., Germany, Japan, United Kingdom, and United States of America) rapidly deployed policies to enhance financial, economic, and/or social resilience, such as government bond buying, wage and rent subsidies, bailouts, loans, and other economic stimulus programs. Vivid Economics [29] "Greenness of Stimulus Index" assessed COVID-19 stimulus efforts by G20 countries and other major economies in relation to climate action and biodiversity goals. They found that as of July 2021, there have been unprecedented governmental financial interventions in response to COVID-19 with stimulus packages varying from US$2 billion (Iceland) to US$5.8 trillion (the USA), making up a total of measured stimulus to US$17.2 trillion. However, in their assessment, Vivid Economics [29] found that of the total announced COVID-19 stimulus packages, only US$1.8 trillion has been "green." Further, they summarized that the stimulus

packages ". . . will have a negative environmental impact in 15 of the G20 countries and economies, and in five of the ten other analysed countries" and "even among leading countries, nature and biodiversity have been particularly neglected." Thus, policymakers and governments have not yet grasped why ecological resilience is equally important as a response to the crisis, let alone the importance of supporting social–ecological resiliency for recovery and prevention of future crises.

What the Greenness of Stimulus Index suggests [29] is that many countries have funneled limited resources into urgent healthcare needs rather than conservation efforts where actions and outcomes are slower moving and more uncertain. There is, therefore, a disjuncture between immediate needs to mitigate the pandemic and longer-term actions to prevent such crises in the future. Societal responses to the pandemic and other social–ecological crises are also hampered by an unwillingness to make decisions in the face of uncertainty and by "creeping normality" [30] where major changes are accepted as normal when they in fact occur slowly through minor, often unnoticeable, increments.

1.3. The Anthropause as a basis for in-action on ecological resiliency

The neglect of nature may have been inadvertently excused by academic and media discussions of an "Anthropause" caused by lockdowns [9] and travel restrictions [8]. The Anthropause narrative was popular and (falsely) comforting as it implied that nature was "healing" during the pandemic due to human absence and therefore did not need policy attention or a resiliency boost, thus absolving humans of responsibility for enacting more difficult long-term changes [31]. Despite the seemingly positive immediate impacts of the Anthropause on nature (e.g., animal species distributions and abundance changes attributed to reduced human activity), a recent meta-analysis revealed that the ecological impacts are complex and mixed. For example, the lockdown also produced negative effects, such as increases in illegal hunting and fishing, mining, wildlife trade, environmental pollution, and deforestation [32]. Thus, Anthropause narratives belie the fact that resource extraction has continued during the pandemic and that business-as-usual continues to cause widespread ecosystem degradation [33] that requires immediate policy attention. In some cases, COVID-19 policy measures further contributed to the problem such as reducing environmental taxes or regulatory enforcement [32,33].

2. Social–ecological impacts of the COVID-19 pandemic

Most of the research on the effects of COVID-19 thus far has focused primarily on the social or ecological impacts even though the pandemic is a much broader issue that transcends singular systems (see references in S1 File). This emphasis is not unexpected given that early COVID-19 research has been largely opportunistic [34]. Indeed, many publications on the (ecological) impacts of COVID-19 were produced very rapidly early on in the pandemic [35], but when synthesized later, suggest truly mixed effects [32]. Moreover, as we emphasized, policy responses to the pandemic have focused singularly on human resilience and have been relatively reactive and unplanned.

Here, we demonstrate how the pandemic has influenced social–ecological interactions in several community-based SES, which serve as example cases. These cases exemplify social–ecological impacts of the pandemic as complex social–ecological interactions and feedbacks that arise from nonlinear causality [36]. We acknowledge that there are many other cases that are beyond the scope of this review. We argue that an SES lens further helps to recognize that these impacts are outcomes of social–ecological systemic inequalities.

2.1. "Anthropause" versus "Anthrocrush" in rural and urban SES

The pandemic has resulted in contrasting effects to rural and urban SES. The Anthropause narrative gives only a partial picture of the impact of the pandemic on human–nature interactions. While some SES are experiencing fewer visitors and reduced impacts, others are experiencing what we term an "Anthrocrush," [37] with more visitors and intensified use (e.g., [38]). International and interregional travel restrictions, along with a desire among urban dwellers to escape the city when possible, have increased the usage of adjacent "open" areas, a phenomenon some refer to as "spillover effects" [39]: Policies that benefit nature in a certain area can negatively impact nature elsewhere, i.e., in another jurisdiction.

The Anthrocrush spillover is likely being felt most acutely in peri-regions of major population centers (e.g., [40]) and has significant consequences for certain SES, while others remain less affected. For example, Ontario Parks (a Canadian provincial system of parks and protected areas) has seen an increase in camping reservations of up to 110% from 2020, which itself was up 50% from 2019, while day use increased up to 120% from 2019 (personal communication). The Parks and their staff have come under enormous ecological (e.g., pollution) and social (e.g., harassment, abuse, fatigue, and emotional) stress (personal communication). Further, "the Atlantic Bubble," a travel-restricted area comprising 4 Atlantic provinces in Canada, has likely reduced pressure to SES in these previously highly vacation-traveled provinces. In comparison, other provinces like British Columbia, Alberta, Ontario, and Quebec have likely experienced an Anthrocrush because they have large urban populations who were restricted to traveling within or among these select provinces. Outcomes and feedbacks after the Anthropause will also require research and policy attention, such as changing patterns of travel that may exacerbate the Anthrocrush. For example, "revenge travel"—the anticipated explosion in tourism after pent-up demand of people wanting to make up for lost time—will swing recovering SES quickly from isolation to overuse [41].

There exist other inconsistent rural–urban social–ecological impacts of COVID-19, including ones at local scales. In India, for example, heavily polluted rivers flowed much more clearly, yet local communities turned to endangered freshwater fish for food [42]. Moreover, in contradiction to the Anthropause, rising urban unemployment has caused people in lower-income countries to return to rural areas with sensitive ecosystems, furthering the idea of a precipitant Anthrocrush [43]. The pandemic has also had immediate profound effects on people's abilities to prevent harm to ecosystems and biodiversity. It disrupted many traditional conservation efforts, such as ground-based monitoring and enforcement of regulations [32,44].

In part due to COVID-19 restrictions (e.g., lockdowns), illegal fishing, poaching, deforestation, agricultural expansion, and mining have flourished in various parts of the world, especially in areas which relied heavily on tourist income prepandemic [43–45]. For example, deforestation nearly doubled from 2019 to 2020 in the global tropics [44], up 51% from a year ago in the Brazilian Amazon, and increased by up to 136% in the African tropics [43,46]. In March 2020, 27 protected birds of prey were illegally killed in Central and Eastern Europe [47], and in the Baltic, a lack of tourists led to a 7-fold increase in presence of white-tailed eagles *Haliaeetus albicilla*, causing 26% lower breeding productivity of common murres *Uria aalge* than the long-term average [48]. In African and Asian countries, poaching, bushmeat harvest, and trafficking have increased [49–50]. Commercial fishing in protected waters spiked in the Philippines and Brazil [51–52]. Some of these negative trends (e.g., higher rates of bushmeat harvest and trafficking and deforestation) increase the risk of future zoonotic disease outbreaks demonstrating a positive feedback loop [53–54].

2.2. Marginalized SES and environmental justice

The impacts of the pandemic also disproportionately affect marginalized SES, thrusting environmental (in)justice issues further into the spotlight [55–57]. Racial and income disparities

manifest in higher exposure to environmental pollutants and greater risk of COVID-19 infection and death due to proximity to pollution [58–59]. Additionally, across the urban–rural spectrum, exposure to much higher levels of industrial chemicals, air pollution, poisonous heavy metals, and pathogens can exacerbate preexisting health conditions, many of which are risk factors for severe COVID-19 [56,60]. Undeniably, in some of the poorest and also most biodiverse parts of the planet, the Anthropause and the wider economic disruption caused by the pandemic have increased poverty and food insecurity while devastating ecotourism and other sources of livelihoods [43].

2.3. Indigenous communities and SES

The pandemic has had unique impacts on Indigenous peoples and communities. A survey with respondents from 40 countries has revealed mixed effects for Indigenous SES [61]. Specifically, it found some positive outcomes such as an uptake of traditional medicine, and an increase in community solidarity, but also negative outcomes such as loss of jobs or livelihood. However, Indigenous communities in remote regions face tremendous challenges, including lack of accessible healthcare, overcrowded housing, and a lack of political control over adjacent natural resources [61,62]. Community resilience in Indigenous communities is linked to the recognition of rights and the ability to govern and access to one's own lands, resources, and knowledge. This resilience buffers the impacts of the pandemic, although it was also compromised during lockdowns [61–62]. For example, on top of COVID-19, communities in Fiji and Benin dealt with additional crises, such as cyclones and the closure of markets to purchase food, which negatively affected community resilience [61]. Moreover, resilience decreases when communities rely heavily on nongovernmental organizations (NGOs) or governments as they become increasingly dependent on external funding or knowledge [61].

The impacts in these SES cases as well as possible policies to address them are simply not visible when studied by social or natural scientists separately and thus require SES frameworks [63] to understand and respond to crises which are social–ecological by nature.

3. The value of a social–ecological systems approach

As more research and actions focus on various aspects of the pandemic's causes and impacts, it is necessary to think more holistically and mobilize existing conceptual tools such as SES. The social–ecological impacts of the pandemic are not well understood [64], yet it is precisely this insight we need to help human societies adapt their responses to this and future social–ecological crises. As the New Scientist [65] claims regarding our lack of progress in this space, "our understanding of the web of dependencies that link us to the natural world is perhaps 30 or 40 years behind the science of climate change." The pandemic exemplifies why it is also necessary to embrace SES-informed integrative and innovative solutions to build social–ecological resilience. SES frameworks can holistically analyze the pandemic as a type of wicked problem—those that are difficult to solve due to incomplete, inconsistent, and shifting solutions which are difficult to distinguish [66].

Ecological research has traditionally underemphasized social factors, while social science research on human–environment relations features a history of anthropocentrism (e.g., [67]). In contrast, SES frameworks (e.g., Driver-Pressure-State-Impact-Response (DPSIR), ecosystem services, and Human-Environment Systems (HES)) study complex, coupled systems that consider the interconnectedness of society and the environment to achieve various empirical, analytical, and/or social–ecological goals [68]. Strategic practices in the SES research field include transdisciplinarity to empower different types of knowledge and inputs, methodological pluralism (use of multiple methods) to enable collaborative research design, and the

generation recommendations for policymakers with a focus on SES sustainability [69]. SES frameworks help to think and plan across scales by identifying social–ecological mismatches between the scales of management and the scale(s) of ecological processes being managed [70,71]. For example, SES approaches facilitated transdisciplinarity to generate unique insights about waterways including mismatches between the water quality in interconnected canal sections, rivers and lakes and their management, helping to identify reductions in SES resiliency [72,73]. Another research example in Namibia revealed that recoupling local SES by taking down National Park fences may benefit long-term conservation of elephants and savanna ecosystems while local people would reap livestock grazing and tourism benefits [74].

Several environmental health concepts consistent with SES frameworks have gained momentum and emphasize social and ecological well-being and recognize humans and the environment as coregulators of the planet: One Health [75–76], Planetary Health [77], and Social–Ecological System Health (SESH) [78]. Effective practical implementation and evaluation of these environmental health approaches is contingent on addressing SES resilience specifically [79]. SES-informed environmental health concepts partially reveal the causes, challenges, and inadequate responses to COVID-19. Social–ecological changes that lead to the spread of the disease do not align with epidemiological surveillance, public health management, nor natural resource management, averting necessary adaptive governance of linked SES [79].

In response to COVID-19, Schneider and colleagues [80] outline 6 social–ecological principles specifically designed to shape future practices of coexistence of societies and nature to prevent future infectious diseases including (1) shifting the focus on relations between society and nature; (2) enabling coexistence of different social groups, but also human and nonhuman subjects; (3) defining and reflecting on limits, in terms of the spatial, temporal, social, and ecological scale; (4) dealing with complexity of social and natural entanglement requires acceptance of our limited degree of control; (5) strengthening resilience of SES; and (6) participation of all actors in these methodological principles.

4. Building back better by embracing a social–ecological systems informed set of research and policy responses

In many ways, the arrival of the COVID-19 infectious disease should be unsurprising given the evidence on how human activities contribute to undesirable destabilizing planetary changes. The "planetary boundaries" concept [81,82], which aims to delineate a safe operating space for humanity, has found that we have already crossed 4 of 9 boundaries (i.e., climate change, loss of biosphere integrity, land system change, and altered biogeochemical cycles), thus undermining the integrity, resilience, and capacity of ecosystems to sustain ecosystem services [83]. The pandemic demonstrates the danger of violating these planetary boundaries, particularly biosphere integrity and land system change, which reduce the capacity of nature to buffer against, regulate, and control disease. It is now abundantly clear that in the Anthropocene, humans are driving a cycle of ecosystem degradation in increasingly closely connected SES which tends to convert ecosystem services (e.g., health regulation) into disservices (e.g., infectious disease).

The COVID-19 pandemic is a planetary crisis and a wake-up call that human well-being is dependent on the well-being of the ecosystems around us. Transitioning to a desirable and sustainable global future will require a societal transformation reconciling humanity with nature in which we can no longer ignore nature in broader resilience strategies [84]. Hence, SES approaches are urgently needed to formulate holistic evidence-based policies and management measures that cost effectively minimize risk to human and environmental well-being simultaneously [85]. Specifically with regard to the COVID-19 pandemic, holistic SES perspectives both in science and policymaking could be achieved by these transformations:

1. Encourage policymakers and governments to embrace social and ecological resilience simultaneously (i.e., social–ecological resilience) as an important response to the crisis.
    i. Develop policy briefs that are framed using SES.
    ii. Develop SES-informed sets of policy responses and management measures with lessons learned for future pandemics.
    iii. Propose and adopt "green" COVID-19 stimulus efforts with economic trajectories that enhance nature and respond to climate change without compromising biodiversity.
    iv. Invest in nature-based solutions (actions inspired, supported, or copied from nature), such as forest protection, ecosystem restoration, and regenerative agriculture to help address public health risks.
    v. Adopt and strengthen approaches that simultaneously assess ecological and human health (e.g., One Health, Planetary Health, and SESH). The UNEP could anchor these approaches in a wider initiative with the Sustainable Development Goals [79].
    vi. Recommend and prescribe initiatives like "A Prescription for Nature" (PaRx, https://www.parkprescriptions.ca) and "Forest therapy" (https://crca.ca/who-we-are/education/foresttherapy) to improve patients' mental and physical health by connecting them to nature.
2. Fund research on COVID-19 and pandemic response that is inclusive of SES, focused on social and ecological impacts of the pandemic.
    i. Enable integrated inter- and transdisciplinary research involving Indigenous and local communities and knowledge holders, which have had long-standing relationships with interconnected ecosystems and whose practices and ways of knowing could help alleviate social–ecological mismatches [86,87].
    ii. Identify potential knowledge brokers that could enable transdisciplinary dialogue between government departments and interdisciplinary research teams.

We must carry lessons forward from the pandemic, recognizing that planetary health and those who steward it are essential in the face of all our wicked social–ecological challenges. If we proactively and strategically include ecological resilience in pandemic response measures, we can reduce the likelihood of, and our vulnerability to, future social–ecological crises while reducing full costs borne by society. For example, thanks to concerted efforts early on in the crisis, Canada and Denmark have reoriented their economies through stimulus spending to make more positive than negative contributions to building resilience through the protection of the climate and biodiversity [29]. The most important lesson may be the simplest: "The relationship between people and nature must be one of interdependence, otherwise we risk overlooking something that Indigenous peoples have known all along: that we are nature and nature is us and failing to see this simple truth is what has gotten us into this mess in the first place"–Tonio Sadik, Director of Environment at the Assembly of First Nations, the main advocacy organization representing Indigenous Peoples in Canada [88].

Supporting information

S1 File. A selection of references that provide early hints (observations, analysis, and projections) of the effects of the Anthropause on social or ecological systems.
(PDF)

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