Annex. Elements of a Planetary Emergency: Environment of Peace Part 1

These papers were commissioned to inform the research and analysis of the Environment of Peace initiative.
They have not been through SIPRI's formal editorial process.

Contents

1. Governing in the Anthropocene

Corey Pattison

Introduction

Identifying, preparing for and responding to security risks are some of the primary functions of governance. This has been the case since the earliest states,[1] though the scope has hence broadened significantly from an exclusive focus on national security, or risk of armed attack by an external foe, to human security, encompassing, inter alia, persistent poverty, epidemics and economic downturns.[2] The broadening perspective on the security concerns of governing reflected important contextual changes—namely, a virtual end to interstate conflict following World War II and a further reduction of nuclear weapons after the cold war. Relatedly, it also reflected a normative shift in the responsibilities of those governing vis-à-vis the governed—from seeing the well-being of the latter as the end rather than a means; or more simply, a growing consensus that security and development are mutually dependent.[3]

Entry into the Anthropocene represents yet another important contextual change with implications for the scope and objectives of governance, be it global, national, or local. Though the epoch is characterized by the profound impact of human beings on the planet, the security risks it entails extend beyond purely environmental ones.[4] Societal stresses arising from environmental change,[5] migration,[6] pandemics[7] and growing inequality[8] each pose unique challenges but also exist as part of larger systemic changes brought on by industrialization, digitalization[9] and globalization.[10] These trends combine to increase interconnectedness at multiple levels between individuals, communities and nations, as well as the rates of technological, economic and social change.[11] Growing interconnectedness and accelerating change have resulted in risks that are multidimensional and compounding—that is, risks that interact to produce a consequence greater than their sum, contributing to increased volatility overall.[12]

Environmental change is a clear example of compound risk. Physical impacts of climate change, like drought, flooding and rising average temperature, pose significant threats to human life in and of themselves. But these impacts are also conditioned by institutional factors, such as the capacity and will of governments to prepare and respond, and the adaptive capacity of individuals and communities themselves.[13] In situations where institutional capacity and inclusiveness are weak, physical impacts of climate change can thus be particularly damaging; worse still, since

[1] Tilly, C., 'War making and state making as organised crime', eds P. Evans, D. Rueschemeyer and T. Skocpol, *Bringing the State Back In* (Cambridge University Press: Cambridge, 1985).

[2] UN General Assembly, Resolution Adopted by the General Assembly on 10 Sep. 2012, A/RES/66/290, 25 Oct. 2012; and UN Development Programme, Human Development Report 1995 (United Nations: New York, 1995).

[3] UN General Assembly, Transforming our world: the 2030 Agenda for Sustainable Development, A/RES/70/1, 21 Oct. 2015.

[4] Smith, D., 'The security space in the Anthropocene', eds E. Lövbrand and M. Mobjörk, *Anthropocene (In)Securities: Reflections on Collective Survival 50 Years After the Stockholm Conference* (Oxford University Press: Oxford, 2021).

[5] UN Development Programme, *Human Development Report 2020: The next Frontier: Human Development and the Anthropocene* (UNDP: New York, 2020).

[6] McAuliffe, M., Khadria, B. and Bauloz, C., *World Migration Report 2020* (IOM: Geneva, 2019).

[7] Jetten, J. et al. (eds), *Together Apart: The Psychology of COVID-19* (Sage: London, 2020); and Elgar, F. J., Stefaniak, A. and Wohl, M. J. A., 'The trouble with trust: Time-series analysis of social capital, income inequality, and COVID-19 deaths in 84 countries', *Social Science & Medicine*, vol. 263 (Oct. 2020).

[8] Elgar, Stefaniak and Wohl (note 7).

[9] Schneider, J., 'The capability/vulnerability paradox and military revolutions: Implications for computing, cyber, and the onset of war', *Journal of Strategic Studies*, vol. 42, no. 6 (19 Sep. 2019); and Lupton, D., 'Digital risk society', eds A. Burgess, A. Alemanno and J. O. Zinn, *Routledge Handbook of Risk Studies* (Routledge: Abingdon, 2016).

[10] Engel, L. C., Rutkowski, L. and Rutkowski, D., 'Global mobility and rising inequality: a cross-national study of immigration, poverty, and social cohesion', *Peabody Journal of Education*, vol. 89, no. 1 (1 Jan. 2014); and Marshall, B. K., 'Globalisation, environmental degradation and Ulrich Beck's risk society', *Environmental Values*, vol. 8, no. 2 (1 May 1999).

[11] Torres, C. A., 'Global citizenship and global universities. the age of global interdependence and cosmopolitanism: global citizenship and global universities. the age of global interdependence and cosmopolitanism', *European Journal of Education*, vol. 50, no. 3 (Sep. 2015); and Rosa, H., *Social Acceleration: A New Theory of Modernity*, New directions for critical theory (Columbia University Press: New York, 2013).

[12] Haimes, Y. Y., 'Risk modeling of interdependent complex systems of systems: Theory and practice: Risk modeling of interdependent complex systems of systems', *Risk Analysis*, vol. 38, no. 1 (Jan. 2018).

[13] Busby, J. W., *States and Nature: The Effects of Climate Change on Security* (Cambridge University Press: Cambridge, 28 Feb. 2022).

these factors simultaneously pose risks for violent conflict, environmental change can also contribute to a broader breakdown of security by further weakening capacity and instrumentalizing grievances related to exclusion. For example, in Mali, worsening droughts can drive competition between social groups over an increasingly scarce or variable resource base. At the same time, weak capacity of local institutions—both a cause and a symptom of ongoing violence—can leave certain segments of the population more exposed to joint environmental and security risks, deepening inequities and driving grievances towards the government. It is for these reasons that climate change is often referred to as a 'threat multiplier'.[14]

The interconnectedness of risks in the Anthropocene poses challenges to existing models of governance in at least two ways. The first is the difficulty to identify the precise form of risks given their compound nature. This is due to substantial practical, conceptual and epistemological limitations to modelling climate-related security risks.[15] For example, their complex interconnectedness requires tracing connections between proximate causes with longer-run, supralocal insights on structural and environmental change. However, bridging different levels of analysis through the identification and isolation of the precise mechanisms whereby macro-level processes, like climate change, may affect actors, institutions and social processes at the micro level has so far proven to be exceptionally challenging.

Yet identification of risks is not enough; the obstacles to risk management must also be identified, prioritized and addressed through private and public action. This leads to a second challenge to existing models of governance. If the first involved largely capacity-related constraints to overcoming cognitive barriers, the second—translating risk identification to risk management—requires a combination of resources, will and behavioural change. The will of states or other actors to direct capacities to prevent, mitigate and respond to security risks is an extension and reflection of the inclusiveness of their political and economic institutions.[16] Inclusive institutions, through which power is broadly distributed in society, create conditions through which citizens, associations, businesses and other stakeholders make claims on leaders to exercise power in the broadest interest of society.[17] Inclusive institutions are no guarantee of peace and stability, but they are the surest way to achieve them. Michael Doyle has argued that 'the absence of war between democratic states comes as close as anything we have to an empirical law in international relations'.[18] Amartya Sen has famously observed that 'there has never been a famine in a functioning multiparty democracy'.[19]

By contrast, states or other polities characterized by extractive institutions are more likely to limit their protection or response to a narrow political base of the regime such as co-ethnics or the leader's home region or provide none at all, increasing vulnerability to the type of interconnected security risks outlined at the outset.[20] Even under inclusive political institutions, risk management can be impaired by government failures stemming from capture by interest groups, corruption of government officials and distortionary policies, since businesses and people who are negatively affected by certain risk management measures will naturally tend to oppose them. Powerful oil and gas lobbies, for instance, have long blocked useful environmental regulations even in the presence of well-established scientific evidence.

The imperative to overcome these challenges is urgent and evident. Even with the most rapid and far-reaching action to reduce greenhouse gas emissions, we can expect the security consequences of climate change to continue to unfold in the near term, given that the consequences of the past decades are already baked in. But the prospect that mitigating action will be untimely and insufficient provides a glimpse of a future, not far off, when governments and communities are overwhelmed by shocks so frequent and devastating—and with resulting needs so great—that they become effectively unmanageable for countries in all regions of the world.[21] There is, then,

14 Swain, A., 'Climate change: national security threat', eds D. A. Bearfield, E. Berman and M. J. Dubnick, *Encyclopedia of Public Administration and Public Policy, Third Edition*, 3rd edn (Routledge: Abingdon, 14 Aug. 2020).

15 Oppenheimer, M. et al., 'Emergent risks and key vulnerabilities', eds C. B. Field et al., *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectorial Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge University Press: Cambridge, 2014).

16 Acemoglu, D. and Robinson, J. A., *Why Nations Fail: The Origins of Power, Prosperity, and Poverty* (Currency: New York, 2012); and Busby (note 13).

17 Acemoglu and Robinson (note 16).

18 Doyle, M. W., 'Liberalism and world politics', *The American Political Science Review*, vol. 80, no. 4 (1986).

19 Sen, A., *Development as Freedom*, Borzoi Book (Alfred A. Knopf: New York, 1999).

20 Busby (note 13).

21 Smith (note 4).

a third, normative dimension to the framework. If the prior dimensions are focused on questions of whether and how institutions provide security as part of governance, they presuppose fundamental questions about what is being secured and from whom or what. As prior changes in the security context led to evolutions in normative approaches to security, the Anthropocene requires a redefinition of public interests in light of risks to a shared security space in which national and human security are merged.[22] This entails an effort not just to understand the complex security implications of environmental change, but to frame the response to those risks within a sufficiently comprehensive framework—the Sustainable Development Goals of the 2030 United Nations Agenda.

These challenges constitute a non-exhaustive set of design requirements for governance in the Anthropocene epoch. The following expands on them to construct a basic framework composed of three parts: (*a*) cognitive barriers to identifying complex risks under deep uncertainty; (*b*) multi-scalar institutional capacity and inclusiveness; and (*c*) normative frameworks that span conceptions of national versus human security.

Analytical and conceptual challenges: Identifying complex risks

Governance in the Anthropocene begins by acknowledging that all people confront risks to their security, but especially those who face the most pressing impacts of climate change in their daily lives—in places where prevalent livelihoods are becoming tenuous, like the Sahel, or where coastal flooding threatens to inundate entire communities, such as small Pacific islands. As outlined above, this acknowledgement must also extend to the fact that people face not one but many interconnected risks. But to manage these risks they must first be identified, understood and communicated, and this is constrained by analytical and conceptual limitations that should be overcome, where possible, and internalized, where they are not.

There is a growing recognition of the role of climate change as a threat to security in terms of increased resource competition, food insecurity, internal migration and severity of natural disasters. A meta-analysis carried out in 2015 found that a 1-degree Celsius increase in temperature was associated with an increase of interpersonal conflict by 2.4 per cent and intergroup conflict by 11.3 per cent.[23] Rising awareness that climate change makes conflict likelier than it would otherwise be is reflected in the common treatment of the former as a 'threat multiplier'. While analytically accurate, in that it aptly illustrates the comprehensive ways in which climate change worsens pre-existing social, political and economic risk factors, this formulation does little to help navigate the complexity of the interconnected nature of these risks or translate to a clear understanding of how these phenomena are linked and what to do about it. Tracing the precise mechanisms by which environmental change influences violent conflict poses significant conceptual difficulties, of course, for the reasons alluded to above.

The difficulties do not end with analytical challenges. The problems of climate change and biodiversity loss are also conceptual since the risks that they introduce are both systemic and deeply uncertain. The first term—systemic—refers to an event that triggers instability or the collapse of an entire system. In the financial context from which it is borrowed, this means the collapse of an entire industry or economy, rather than an individual firm; in the context of climate change and biodiversity loss, this means the breakdown of entire ecosystems and planetary systems and the human societies which depend on them. Uncertainty applies in two senses; the first relays uncertainty regarding events which are unknown—whether and when national pledges to decarbonize will be met, for example—but where the outcomes contingent on those targets are understood, at least broadly—that is, the biophysical and socioeconomic conditions which are estimated to result from different emissions pathways. By contrast, environmental security also implicates the notion of deep uncertainty, or 'unknown unknowns'. The possibility of reaching environmental tipping points, which may trigger a cascade of complex interactions, introduces a level of uncertainty about how extensive security breakdowns may be because the full range of catastrophic impacts may lay outside our current conceptions of human and international

[22] Cass, L. R., 'Measuring the domestic salience of international environmental norms: Climate change norms in American, German and British climate policy debates', ed. M. E. Pettenger, *The Social Construction of Climate Change: Power, Knowledge, Norms, Discourses* (Ashgate Publishing Limited: Aldershot, 2007).

[23] Burke, M., Hsiang, S. M. and Miguel, E., 'Climate and conflict', *Annual Review of Economics*, vol. 7, no. 1 (1 Aug. 2015).

relations. It should be clarified, and emphasized, that deep uncertainty here refers not to whether catastrophic effects may ensue from continuing on our current trajectory of carbon emissions and biodiversity loss; there is scientific consensus around what the thresholds are, roughly, and what the proximate impacts may likely be of reaching them. But combined with its systemic nature, the comprehensive and paradigm-shifting impacts of environmental tipping points enhance the difficulty of forecasting long-term security risks in the Anthropocene.

Some of the analytical challenges are surmountable, and governance models should find ways to leverage diverse types of knowledge to help overcome them. For example, the links between climate change, biodiversity loss and violent conflict are not inscrutable. An emerging literature demonstrates, for example, that agriculturally dependent societies that exhibit high levels of political exclusion are at the highest risk,[24] offering insights into geographic areas at highest compound risk, as well as pointing to a road map of reform to mitigate the risks. Findings of both conflict prevention and emergent climate-security literature alike privilege the role of social and economic exclusion as central to explaining why conflict occurs and why its impacts are disproportionately felt by certain groups. These findings should focus our attention on the social processes of exclusion that not only make certain groups more vulnerable to the impacts of environmental damage and conflict, but can, themselves, drive conflict. Where efforts to improve the inclusion of local institutions reinforce efforts to help local communities map the everyday security risks that they face, we begin to approach governance models capable of encompassing the full range of complexity of environmental security risks. This is the objective of a World Bank local governance project in Guinea, for example. The project facilitates identification of local climate and security risks by communities, as well as priority investments to manage them, which are included in local development plans to be financed by Guinea's decentralization funds.

It is neither realistic nor necessary that governance models should eliminate uncertainty, however. Decision making under uncertainty is a defining feature of individual and collective life. Farmers choose crops to cultivate without knowing exactly how much rain there will be or what market demand will look like at harvest. Central banks set interest rates in the presence of uncertain external conditions, like financial markets or domestic productivity growth.[25] Indeed, the analysis of decision making under uncertainty has been a central focus of economics and public policy since at least 1700.[26] And, of course, military decision makers must make urgent decisions with incomplete information that have clear life-and-death implications; hence, the term 'the fog of war'.

Rather, these observations demonstrate that incorporating uncertainty is a critical part of governance, perhaps even more so in the Anthropocene, since to do otherwise means leaving those most exposed to environmental hazards and conflict risks to navigate them alone. Recognizing the complex, systemic and uncertain nature of Anthropocene risks shifts the emphasis to sharing risk assessments and burdens with others to help overcome these barriers through collective action and institutions. An effective governance system to manage these risks thus begins with mechanisms aimed at improving our common understanding of interlinked environmental security phenomena through collective and participatory approaches. By extension, the importance of building common understanding of risk assessments across different actor groups implicates trade-offs within artificial intelligence (AI) and other 'black box' approaches to risk identification, where the inner workings of the methodology are understood by only a small handful of experts.

The distinctive characteristics of Anthropocene risks also point to the categories of security risks which should be prioritized under Anthropocene governance models. For example, under conditions of deep uncertainty noted above, governance models should emphasize the hedging risks with low probability but high impact, given the potential for cascading, systemic effects. The corollary is that plans which are designed for the most likely outcomes but that increase the vulnerability to less likely events should be avoided. Instead, governance models should promote adaptive policies that lead to acceptable outcomes in a large range of scenarios and that can be revised when new information is available and when the context changes.

[24] Busby, J. and von Uexkull, N., 'Climate shocks and humanitarian crises', *Foreign Affairs*, 29 Nov. 2018.

[25] World Bank, *World Development Report 2014: Risk and Opportunity: Managing Risk for Development* (World Bank: Washington, DC, 7 Oct. 2013).

[26] This marks the introduction of utility optimization by Daniel Bernoulli.

Institutional challenges: Capacity and inclusiveness of and between overlapping systems

Systemic risks can hardly be managed by individuals alone. They require a broad range of governance systems, spanning local neighbourhood communities to states to supranational institutions operating on the principles of subsidiarity and comparative advantage.[27] For example, communities have an advantage in managing small systemic risks (such as local violence or flooding) because of their proximity to the groups of people affected and their potential advantage in monitoring and resolving local tensions. However, risks often exist on a scale that communities are simply not equipped to handle. For example, neighbourhoods are potentially able to maintain their own drains, but urban flood prevention requires citywide drainage and land use planning that only city governments can provide. Similarly, neighbourhoods can patrol against individual criminals, but they are outmatched by the capacity of organized crime networks. When large systemic risks cross national borders or overwhelm national capacities, support and coordination from the international community is needed. The relative importance of communities, non-state service providers, like civil society and local religious and non-governmental organizations, and international humanitarian and development actors varies in relation to the capacity of the state. In less developed countries, and especially in fragile and conflict-affected countries, informal mechanisms tend to be more prevalent and the relative roles of the community and non-state actors are larger. For these countries, the international community may also play a larger role through financial assistance and capacity building.

Yet it is the question of state capacity which remains the primary focus of governance in terms of managing environmental security risks. The state has a unique role in managing large systemic risks because it has the scale and tools to prepare at the national and regional levels. Moreover, states occupy a privileged position in this Westphalian world: states make and enforce domestic law, possess significant financial resources, based on their powers of compulsory taxation, and are uniquely capable of claiming to act legitimately for the common good of their citizens.[28] And, of course, it is states that conclude agreements at the international level.

State capacity refers to the ability to mobilize the state's administrative apparatus to identify risks, mitigate those they can and adapt to those they cannot prevent. Frequently discussions of state capacity build on Mann's concept of 'infrastructural' (as opposed to 'despotic') power: the capacity 'to implement logistically political decisions throughout the realm'.[29] Francis Fukuyama's definition of governance as the ability to 'make and enforce rules' is also apt here,[30] though perhaps better rephrased as the ability to make and deploy plans, through mobilization of the state's bureaucratic, informational and fiscal resources.[31] Especially in the context of environmental change, conceptualizing state capacity requires us to take stock of the resilience of institutions—their ability to respond to shocks. As such, a better definition of state capacity might be the ability of the state 'to mobilize and deploy resources in planning, enforcement and response'.[32]

What does this look like in practice and how does one objectively assess the capacity of one state relative to another? Existing data sets on state capacity are plentiful, with opinions generally divided between quantifiable, objective indicators (such as tax revenues) versus perception-based indicators (perceptions of how tax revenue is translated into services). The World Bank's Worldwide Governance Indicators draw on surveys and appraisals from researchers, non-governmental organizations (NGOs) and public officials to assess at six dimensions of government—Voice and Accountability, Political Stability and Lack of Violence, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption—of which two, Government Effectiveness and

[27] Subsidiarity is the principle that social and political issues should be dealt with at the most immediate level that is consistent with their resolution to take advantage of greater proximity to and knowledge of risk. Comparative advantage suggests that risks should be managed by the actor or system most capable of doing so. World Bank (note 25).

[28] Tilly (note 1).

[29] Mann, M., 'The autonomous power of the state: its origins, mechanisms and results', *European Journal of Sociology/Archives Européennes de Sociologie*, vol. 25, no. 2 (Nov. 1984).

[30] Fukuyama, F., 'What Is Governance?', *Governance*, vol. 26, no. 3 (2013).

[31] Lindvall, J. and Teorell, J., *State Capacity as Power: A Conceptual Framework* (Department of Political Science, Lund University: Lund, May 2016).

[32] Busby (note 13).

Regulatory Quality, might fall under the rubric of 'state capacity'.[33] Hanson and Sigman's data set divides state capacity into three axes—extractive capacity, coercive capacity and administrative capacity—based on twenty-four indicators, stretching from statistical capacity to monopoly on the use of force to administrative efficiency.[34]

In the context of climate change adaptation, the UN Hyogo Framework for Action provides yet more nuanced criteria. Born of a 2005 conference, the self-assessment asks countries to evaluate: (*a*) the degree of national and local institutions' commitment to disaster risk reduction; (*b*) their capacity for early warning; (*c*) their ability to harness knowledge, innovation and education to promote resilience; (*d*) the reduction of underlying risk factors; and (*e*) the strengthening of disaster preparedness for effective response at all levels.[35]

It would be naive to ignore the fact that states often fall far short in fulfilling these criteria, however. This is all too vividly evident in the case of fragile and conflict-affected countries. Communities and non-state actors play an important role across all configurations of citizen–state relations but are especially important service providers where the state is weak or absent. Communities are groups of people who interact frequently and share location or identity. Neighbourhood groups, religious groups and kinship groups are some examples. They work through informal networks based on trust, reciprocity and social norms—what James Coleman and Robert Putnam call 'social capital'.[36] Communities almost always have more knowledge about local circumstances and can therefore set priorities and produce more appropriate policy designs than centralized planners;[37] they also have greater incentives and greater ability to influence local affairs.[38]

Reliance on personal interactions and informal means of enforcement underlies the strength of communities, but it is also the source of their weakness. Communities are not necessarily fair or inclusive; they can be marked by strong inequalities in power and wealth. They may exclude vulnerable people (chronically ill, widowed), new entrants (migrants, refugees), or those who happen to be different (ethnic minorities). Exclusion has the dual, and mutually reinforcing, effects of systematically exposing some groups to greater likelihood and impact of climate hazards, while also generating grievances towards the state for failing to provide the required support.

The question of inclusion is thus intimately related to that of capacity, and not only at the local level. The effective and legitimate deployment of capacity hinges on the inclusiveness of the institution(s) in question. As Sen's quote above underlines, democratic processes incentivize political leaders to be more attentive to citizens' needs, while freedoms of speech and press facilitate better information—prompting governments to contend with events, even when the news is unpleasant. Inclusion urges responsiveness to real conditions, while also making policymakers more responsive to a wider swathe of competing stakeholders within a population.[39] The measure of inclusion is not strictly political in the narrow sense of electoral politics. Acemoglu and Robinson define inclusion as characterized by 'power broadly distributed in society' with institutions that 'constrain its arbitrary exercise'.[40]

More than an asset to effective technocratic performance, though, inclusion is necessary to ensure the peaceful moderation of differences among competing stakeholders in a society. At each level, governance is a continuous dialogue between formal institutions, business, community and civil society. Who is included in this bargaining, who is excluded and what barriers block entry determine not only the selection and implementation of policies;[41] conflict often arises out of exclusion from this dialogue and a subsequent sense of unequal distribution of power and resources.[42] Inclusive processes in institutions (both in and outside of government)

[33] Kaufmann, D., Kraay, A. and Mastruzzi, M., *The Worldwide Governance Indicators: Methodology and Analytical Issues* (World Bank: Washington, DC, 1 Sep. 2010).

[34] Hanson, J. K. and Sigman, R., 'Leviathan's Latent Dimensions: Measuring State Capacity for Comparative Political Research', *The Journal of Politics*, vol. 83, no. 4 (Oct. 2021).

[35] Childs, D., Gordy, M. and Gordon, M., *Implementation of the Hyogo Framework for Action*, UNISDR/GE/2013/5 (UN Office for Disaster Risk Reduction: Geneva, 2013).

[36] Putnam, R. D., *Bowling Alone: The Collapse and Revival of American Community* (Simon & Schuster: London, 2000); and Coleman, J. S., 'Social Capital in the Creation of Human Capital', *American Journal of Sociology*, vol. 94 (Jan. 1988).

[37] Rauken, T., Mydske, P. K. and Winsvold, M., 'Mainstreaming climate change adaptation at the local level', *Local Environment*, vol. 20, no. 4 (3 Apr. 2015).

[38] Agrawal, A., 'Local institutions and adaptation to climate change', eds A. Norton and R. Mearns, *Social Dimensions of Climate Change: Equity and Vulnerability in a Warming World* (World Bank: Washington, DC, 2010), p. 8.

[39] Sen (note 19).

[40] Acemoglu and Robinson (note 16).

[41] Rothstein, B., 'Good governance', ed. D. Levi-Faur, *The Oxford Handbook of Governance* (Oxford University Press: 29 Mar. 2012).

[42] Lara, F. J. Jr. and Champain, P., *Inclusive Peace in Muslim Mindanao: Revisiting the Dynamics of Conflict and Exclusion* (International Alert: London, 2009); Opotow, S. and Weiss, L., 'New ways of thinking about environmentalism: denial and the process of moral exclusion

are thus critical for generating widespread perceptions of their legitimacy, so that they can be accepted as arbiters of competing claims by different groups within society. This is particularly important for mitigating and adapting to climate change, as it involves complex and contested decisions and difficult policy choices, which entail redistribution of significant costs and benefits among society.[43] Under conditions where the state's legitimacy is contested, there is not only a higher chance of failing to achieve policy outcomes—hence the link to capacity—but also that the distribution of costs on certain groups may provoke conflict by exacerbating grievances.

The foregoing observations highlight the mutually reinforcing notions of capacity and inclusion for the ability of institutions to effectively implement policies to prepare for and respond to environmental security risks. While state institutions are central, different configurations of institutions—formal and informal, local, national and international—also reinforce each other by filling gaps, as highlighted by the example of community and non-state actors above. But their interactions are more diverse than that, including, inter alia, advocacy, norm-sharing and coercion. These point to the dynamic nature of institutions in a system of overlapping governance systems. Returning to the example above in which community institutions exclude certain groups, governments and NGOs can play a role by providing essential public goods and promoting inclusion and respect for diversity through enacting anti-discrimination laws, conducting educational campaigns and encouraging interactions that promote cohesiveness. Where the states behave similarly, international development assistance intended to build capacities over time can also be conditioned on the inclusion of certain marginalized groups.

The interaction of governance systems need not be exclusively vertical, however. Increasing interconnections and shared risks have led to a rise in horizontal networks that facilitate the transfusion of ideas and norms and provide key forums for coordinating policy. Cities, for example, have been on the front lines of climate change mitigation and adaptation, at times exhibiting political leadership on climate change where states have been laggard. They face unique risk factors and impacts of climate change: environmental (air pollution, the urban heat island effect); social (in-migration and the growth of informal settlements); and economic (the high costs of climate shocks).[44] Cities can be laboratories for change, with their potential to effectively implement inclusive, locally appropriate solutions. But it is the networks within and of cities that makes the marriage of local knowledge with institutional capacities, with the power to make plans and implement them. Global and regional networks of cities—the C40 Cities Climate Leadership Group and the World Mayors Council on Climate Change to name but two examples—have emerged as examples of networks which span local and global scales.[45] Cities are well-positioned to galvanize internal coalitions of community-based organizations, business and local governments towards climate action,[46] while networks of cities enable the transmission of knowledge from local experiments, which promotes the creation of new norms held to accountability by peers. Although their limited fiscal resources expose the limits of cities' institutional capacity relative to the state, this has also spawned innovation. Creative financing models for urban climate strategies, drawing on carbon finance, bonds and public-private partnerships, highlight the role of private sector institutions in urban networks of climate change governance.[47]

Regional organizations recall cities in that they are networked—their significance stems from the dialogues of their constituent parts. A community of peers bound by shared challenges and a common fate (by dint of their geography), regional organizations similarly offer a framework for the transmission of knowledge, evolution of norms and mutual accountability. The Intergovernmental Authority on Development (IGAD) which was originally founded in the wake of regional drought, has adopted a 15-year regional climate security strategy in the wake of the Paris climate accord and has formed regional early-warning systems. The Association of Southeast Asian Nations (ASEAN) has, for example, initiated the Multi-Sectoral Framework for Climate Change and Food Security. Regional organizations can complement weak state capacity with technocratic intervention. But this does not happen in a political vacuum. The role of external donors (often

in environmental conflict', *Journal of Social Issues*, vol. 56, no. 3 (Jan. 2000); Asal, V. et al., 'Political exclusion, oil, and ethnic armed conflict', *Journal of Conflict Resolution*, vol. 60, no. 8 (Dec. 2016); and Germann, M. and Sambanis, N., 'Political exclusion, lost autonomy, and escalating conflict over self-determination', *International Organization*, vol. 75, no. 1 (2021).

[43] Aklin, M. and Mildenberger, M., 'Prisoners of the wrong dilemma: why distributive conflict, not collective action, characterizes the politics of climate change', *Global Environmental Politics*, vol. 20, no. 4 (Nov. 2020).

[44] World Bank, *Guide to Climate Change Adaptation in Cities* (World Bank: Washington, DC, 2011).

[45] World Bank (note 44).

[46] World Bank (note 44).

[47] World Bank, *Climate Finance in the Urban Context*, Issues Brief no. 4 (World Bank: Washington, DC, Nov. 2010).

Western powers) in shaping the climate action of regional intergovernmental organizations has been noted. Internally, regional power politics can be an agent of exclusion within regional organizations, dampening prospects for multilateral cooperation. This has been the case for the South Asian Association for Regional Cooperation (SAARC). The organization is paralysed by the India–Pakistan dispute, without a regional summit since a 2016 flashpoint between the two rivals. Smaller member states have sought out collaboration through alternative networks, sometimes with other regional organizations. The Asian Disaster Preparedness Center (ADPC), for example, of which the Bangladeshi government is a national government development partner, draws on a broad network of international, national and subnational institutions, both governmental and non-governmental; among these are the regional organizations ASEAN, the Secretariat of the Pacific Community (SPC) and the Mekong River Commission (MRC), in addition to SAARC.[48]

The story of Pacific Small Island Developing States (SIDS) in international climate diplomacy similarly highlights the potential for power politics to drive exclusion and injustice in international processes—and the promise of political coalition building as a counterweight dynamic. Pacific SIDS account for 0.03 per cent of global greenhouse emissions but are uniquely, indeed existentially, threatened by climate change.[49] Rising sea levels, ocean acidification, coastal erosion and extreme weather events endanger the livelihoods, food and water security of Pacific SIDS; already, 10 of the top 30 countries with the highest annual disaster losses as a percentage of gross domestic product are located in the Pacific.[50] The slogan of the Pacific SIDS in climate change diplomacy—'1.5 to Stay Alive'—reflects the catastrophic projections for these countries if global warming exceeds a temperature rise of 1.5°C. While the long-term threat is of rising sea levels drowning low-lying islands, displacement of island populations is already underway as a result of salt water intrusion and food insecurity.[51]

By dint of their location in the geographic 'buffer zone' between Asia and the United States, the Pacific SIDS are trapped in the web of great power politics, balancing a growing reliance on China (e.g. through infrastructure projects) with traditional security relationships with the USA, Australia and New Zealand. Within this 'new cold war' environment, the priorities of the Pacific SIDs, who emphasize climate change as their single greatest security threat, can be subsumed in the wider web of more 'traditional' or 'hard' security interests. The Pacific SIDS have limited diplomatic leverage on the major powers they rely on to make good on their commitments to greenhouse gas emission reductions.[52]

Coordinating and prioritizing climate change in their regional policy architecture (particularly through the Pacific Islands Forum), the Pacific SIDS have joined forces in various formal and informal groupings in the international climate regime, amplifying their voice through coordination and coalition building to overcome what former Marshall Islands Foreign Affairs Minister Tony de Brum called 'the practical and psychological barriers to accessing UN talks'.[53] In the lead-up to the 2015 Paris climate convention, the Marshall Islands offered a case study of a country punching above its diplomatic weight. Convening the High Ambition Coalition, an informal group of approximately 40 countries committed to progressive proposals, the small Pacific Island state was able to secure some of the region's most ambitious goals, including the language related to limiting temperature increases to 1.5°C above pre-industrial levels.[54]

The example of the Pacific SIDS underscores the power of networks in a world where they remain insufficiently inclusive.[55] As with networks of city governments pressing ahead with bold action in circumvention of more powerful, yet passive, national institutions, their success in Paris highlights an emerging political strategy. But the risks they face also illustrate a new security risk typology that combines aspects of national and human security—a fundamental challenge to sovereignty, but with no armed actor at the gate. This is slow-onset risk, without an

[48] Krampe, F. and Mobjörk, M., 'Responding to climate-related security risks: reviewing regional organizations in Asia and Africa', *Current Climate Change Reports*, vol. 4, no. 4 (Dec. 2018).

[49] Pasisi, C., *Climate Security Expert Network, and Sustainable Pacific Consultancy, Climate-Fragility Risk Brief: The Pacific Islands Region* (adelphi: Berlin, 12 Nov. 2019).

[50] World Bank, 'Weathering financial shocks from disasters in the Pacific Islands', 1 Nov. 2018.

[51] World Bank (note 50).

[52] Paskal, C., *Global Warring: How Environmental, Economic, and Political Crisis Will Redraw the World Map* (Key Porter Books: Toronto, 2010).

[53] Goulding, N., 'Marshalling a Pacific response to climate change', eds G. Fry and S. Tarte, *The New Pacific Diplomacy*, Pacific Series (ANU Press: Canberra, 2015).

[54] Goodell, J., 'Will the Paris climate deal save the world?', *Rolling Stone*, 13 Jan. 2016.

[55] Naím, M., *The End of Power: From Boardrooms to Battlefields and Churches to States, Why Being in Charge Isn't What It Used to Be* (Basic Books: New York, 2014).

obvious, clear and present danger. And while it resounds with the broad focus of human security on development as a means of protection from poverty, disease and crime, it exposes profound contradictions in the underlying paradigms of growth and prosperity on which that development would rely without far-reaching reform.

Normative challenges: Forging cooperation in a fracturing world

Taken together, these challenges and associated design requirements for a governance model of environmental security risks point away from simple, state-centric approaches to governance towards more complex ones. Acknowledgement of the increasingly diverse types of institutions and actors who play a key role in governing underlines the need to deal with normative differences among contexts and geographies. It also accentuates the fact that we are more mutually dependent with other peoples than ever before. And just as this poses risks, as foregoing sections have highlighted, it is also a foundation for realigning national and human security approaches. Thus, in complement to the important analytical and organizational considerations implied by the preceding analysis, the final dimension of this framework focuses on the conceptual and normative shifts required to redefine security in the Anthropocene.[56] This entails an effort not just to understand the potential implications of environmental change, and communicate the costs and benefits of possible mitigation and adaptation responses, but to help instil a shift in thinking about how such change impacts a shared security space that connects human welfare, national sovereignty and planetary boundaries.

Such an effort is hardly academic; its goal should be to reframe the understanding of environmental security so that societal majorities can be achieved in favour of necessary mitigation and adaptation policy regimes.[57] Highlighting the risks to national security emanating from climate change has been an effective means of rallying institutional attention and resources to the latter. At the same time, the securitized language of 'crisis' and 'emergency' can evoke the need for post-political, technocratic solutions,[58] while the militarization of climate threatens to put it in a basket with drugs, cancer and terror as the abstract, shifting target in another forever war. To securitize the climate issue is to run the risk of tallying tactical successes in the absence of a strategy.

What is necessary, then, is to reimagine security in the Anthropocene.[59] For policymakers to prioritize climate change because it, say, endangers military installations risks missing the forest for the trees. This work is well under way, with the growing chorus of thinkers who situate the climate issue in a conception of security that bridges the notion of 'human' and 'hard' security. Naturally the remit of humanitarians and development workers, the idea of putting the human at the centre of our security conception has proved universally salient during the Covid-19 pandemic, whose shock and long-lasting aftershocks left a shared trauma on citizens and institutions. Yet, simultaneously, the ambient USA–China tension in which the crisis was managed underscored the enduring relevance of 'hard' security in a multipolar world. But perhaps the most memorable legacy of the pandemic is the global scramble for vaccines, which mobilized national security establishments to promote the health of citizens—and ease the stress on institutions and societies. The overlap of individual, national and international interests during Covid-19 pushed societies to an emerging norm, where the fate and actions—indeed, the security—of individuals and the global society are understood as deeply entwined even within the arena of inevitable contestations.

This example illustrates how traditional notions of security—Hobbesian understanding of security as protection from violence or Machiavellian understanding of security as the survival of the regime—must be conceptually broadened and refreshed to incorporate the role of the environment as a conduit linking individual and collective security. The strategic and organizational corollary of this conceptual shift is to better complement the classic instruments of defence and

[56] Cass (note 22).

[57] Mitchell, R. B. and Carpenter, C., 'Norms for the earth: changing the climate on "climate change"', *Journal of Global Security Studies*, vol. 4, no. 4 (1 Oct. 2019); Alló, M. and Loureiro, M. L., 'The role of social norms on preferences towards climate change policies: a meta-analysis', *Energy Policy*, vol. 73 (1 Oct. 2014); and Nilsson, A., von Borgstede, C. and Biel, A., 'Willingness to accept climate change strategies: the effect of values and norms', *Journal of Environmental Psychology*, vol. 24, no. 3 (1 Sep. 2004).

[58] Calhoun, C., 'The idea of emergency: Humanitarian action and global (dis)order', eds D. Fassin and M. Pandolfi, *Contemporary States of Emergency: The Politics of Military and Humanitarian Interventions* (Zone Books: New York, 2010).

[59] Smith (note 4).

state diplomacy with economic aid, institutional capacity building and human development. Yet, recognizing the unprecedented interconnectedness of risks as a defining feature of security in the Anthropocene, 'the most important instrument for managing and reducing risks is cooperation, which, is henceforth the foundation of security'.[60]

Despite the obvious need for collective efforts, however, signs suggest that a warming world will be a less cooperative one.[61] Trends in violent conflict have largely reversed after decades of decline,[62] as has a trend towards representative democracy;[63] increasing multipolarity has been accompanied by increasing belligerence and a toxicity in political discourse.[64] In a world of tremendous inequality—in wealth and opportunity—expertise has become a proxy for privilege in many quarters, and thus the target of scorn.[65]

These trends suggest that the ability to inspire necessary broad societal shifts is under attack at the very moment when it is most needed, highlighting the importance of leadership and bold ideas. The power of radical ideas is sometimes neglected in policy discourse, where vague, voguish 'clean', 'green' and 'smart' solutions can deflect from serious reckoning with the sheer extent of the transition required.[66] But just because some policy alternatives appear unthinkable today, does not mean they will remain so always. Increasingly, actors in the national security and climate action space acknowledge that the 'ideal' policy option in fact depends on the possibility of redefining what is considered 'normal', 'possible' and 'acceptable'.[67]

Norms are not changed overnight, but through inclusive processes that slowly shift the needle of consensus within society, nudged along by leaders who challenge us to reimagine what is possible—and translate words to action. Around an issue such as climate change, whose harms are psychologically remote,[68] whose vast collectiveness taxes our empathy,[69] there is urgency for norms and policy processes to evolve mutually, mutually driving inclusion, legitimacy and ambition in the other. There is no escaping politics here, in the grandest sense of the term, both in negotiating the ambitions of the normative shift and in how to effect it. Leadership is the inevitable quality necessary to drive consensus building towards new horizons. Should the leadership required to reimagine be bottom-up or top-down, through the example of elites or the pressure of mass protest? Are standards of accountability on new norms to be forged through international law—in reimagining notions of territorial sovereignty, liability and reparation?[70] Change comes from networks within and of institutions—in conscientious attention and word choices by the media,[71] in the reframing of climate hazard and costs by economic decision makers,[72] in innovators urging consumers to new consumption habits, and in governments making unprecedented public commitments and investments in energy efficiency technologies and infrastructures.

[60] Smith (note 4).

[61] Bukharin, I., 'Environmental multilateralism: climate change and american decline', *Swarthmore International Relations Journal*, no. 2 (2017); and Fehl, C. and Thimm, J., 'Dispensing with the indispensable nation?: multilateralism minus one in the trump era', *Global Governance: A Review of Multilateralism and International Organizations*, vol. 25, no. 1 (1 Mar. 2019).

[62] UCDP Conflict Encyclopedia, Uppsala Conflict Data Program, accessed 26 June 2021.

[63] Lührmann, A. et al., *Democracy Report 2020: Autocratization Surges—Resistance Grows* (University of Gothenburg, Varieties of Democracy Institute, V-Dem: Gothenburg, Sweden, Mar. 2020).

[64] Lucas, C. H., 'Concerning values: what underlies public polarisation about climate change?', *Geographical Research*, vol. 56, no. 3 (2018).

[65] Thunert, M., 'Waning trust in (scientific) experts and expertise? Recent evidence from the United States and elsewhere', eds G. Leypoldt and M. Berg, *Authority and Trust in US Culture and Society: Interdisciplinary Approaches and Perspectives*, transcript (Verlag, 28 Feb. 2021).

[66] Scoones, I. and Stirling, A., 'Uncertainty and the politics of transformation', eds I. Scoones and A. Stirling, *The Politics of Uncertainty: Challenges of Transformation*, 1st edn (Routledge: Oxford, New York, 14 July 2020).

[67] Giridharadas, A., 'How America's elites lost their grip', *Time*, 21 Nov. 2019).

[68] Gifford, R. et al., 'Temporal pessimism and spatial optimism in environmental assessments: an 18-nation study', *Journal of Environmental Psychology*, vol. 29, no. 1 (1 Mar. 2009); and Leiserowitz, A., 'Climate change risk perception and policy preferences: the role of affect, imagery, and values', *Climatic Change*, vol. 77, nos 1-2 (21 Aug. 2006).

[69] Slovic, P., 'If I look at the mass I will never act: Psychic numbing and genocide', ed. S. Roeser, *Emotions and Risky Technologies*, International Library of Ethics, Law and Technology, vol. 5 (Springer Netherlands: Dordrecht, 2010).

[70] Schrijver, N., 'The impact of climate change: challenges for international law', eds U. Fastenrath et al., *From Bilateralism to Community Interest: Essays in Honour of Bruno Simma* (Oxford University Press: Oxford, 17 Mar. 2011).

[71] Carrington, D., 'Why the Guardian is changing the language it uses about the environment', *The Guardian*, 17 May 2019.

[72] Harris, P. G. and Symons, J., 'Norm conflict in climate governance: Greenhouse gas accounting and the problem of consumption', *Global Environmental Politics*, vol. 13, no. 1 (Feb. 2013).

2. Human Security Risks in the Anthropocene

Albert Norström,[* **] Victor Galaz[*] and Cibele Queiroz[* **]

Humanity as part of the biosphere

The environment is not an externality to human systems. The biosphere is a precondition for social justice, economic development and sustainability

Work on the interplay between nature and society has a long history. The concept of social-ecological systems is one interpretation to emerge from this history. A social-ecological systems (SES) approach rejects the perceived dichotomy between nature and society, and views places as integrated systems of people and nature. In the SES approach, the 'social' refers to the human dimension in its diverse facets (e.g. the economic, political, technological and cultural) and the 'ecological' to the thin layer of planet Earth where there is life, the biosphere.

The Earth's biosphere encompasses all ecosystems (terrestrial, freshwater and marine) and their plant, animal and microbial life (Mace et al. 2012, Folke et al. 2016). Human development directly depends on this thin layer of life as a resource base that supports and enhances human well-being in all its dimensions (e.g. quality of life in terms of freedom and choice, good social relations, personal security and material needs). For example, the provision of nature contributions to people (NCPs), such as food, timber, fibre, clean air, drinking water and medicines, would be impossible without a functioning biosphere (Díaz et al. 2018, IPBES 2019). Equally embedded in the biosphere are the so called non-material NCPs—dimensions of human well-being that are intangible and unquantified (e.g. cultural, spiritual and relational), and therefore often excluded from development decision making (Pascual et al. 2021).

The biosphere plays a key role in moderating the rest of the Earth system, including the climate system, through its dynamic interplay with the atmosphere, water cycle and biogeochemical cycles. For instance, the biosphere drives global biogeochemistry (e.g. carbon, nitrogen or phosphorus cycling between air, water and land), which affects global climate, soil fertility and ocean productivity (Steffen et al. 2011). The biosphere also moderates the cycling of water, controlling where it rains and how much, how this water flows across the land, where it ends up and in what state, and finally the rate at which it evaporates and returns to the atmosphere (Rockström et al. 2014). Changes in the species making up the biosphere, their abundance, distribution or diversity, have implications for food, water and climate security aspects of human development. This is because species perform different key ecosystem functions that underpin these processes and benefits. Furthermore, the genetic and species diversity making up the biosphere is crucial to its ability to persist and adapt under changing conditions, as it allows for response diversity—the variety of responses to a particular disturbance among organisms performing the same ecosystem function (Elmqvist et al. 2003). It is the interplay between functional and response diversity that allows for the stability of ecosystem functions and services over time and that contributes to the resilience of the Earth system and human development to the rapidly rising speed, scale and risks of the Anthropocene (Mace et al. 2014).

A key feature of the SES approach is that it goes beyond a singular focus on the one-way flow of materials from the biosphere to people (i.e. the dependency of humans on nature), to fully acknowledge the dynamic interactions, feedbacks and co-development linking people and the biosphere across space and time. It emphasizes that people, communities, economies, societies, cultures are embedded parts of the biosphere and shape it, from local to global scales. At the same time people, communities, economies, societies, cultures are shaped by, dependent on and evolving with the biosphere, including a stable climate system (Folke et al. 2011, Haider et al.

* Stockholm Resilience Centre, Stockholm University.
** Global Resilience Partnership.

2021). Just as there is no economy without a society in which it is embedded, there is no society that is not embedded in the biosphere. Human development cannot therefore be decoupled from the biosphere, regardless of human ingenuity and technology. Therefore, focusing primarily on wealth and inequality or social resilience while remaining ignorant about and disconnected from the biosphere and its stewardship is not a recipe for long-term sustainability for people on Earth.

Human development needs to stay within planetary safe operating spaces

One of the most prominent frameworks to summarize how changes in the Earth system and the biosphere underpin human prosperity in fundamental ways, is the 'planetary boundaries' framework. It was developed by Rockström et al. (2009) and identifies nine boundaries related to critical Earth-system processes. These nine boundaries jointly define a 'safe operating space', within which it is argued the relatively stable Earth conditions of the Holocene may be maintained. Of the seven measured planetary boundaries, four are currently transgressed (biosphere integrity, climate change, biogeochemical flows and land-system change) (Steffen et al. 2015b). An important update was published in 2018, with a stronger focus on the longer-term risks of planetary change (Steffen et al. 2018). Steffen and colleagues suggest that as human activities continue to modify several aspects of the Earth system in profound ways, for example, through climate change, 'self-reinforcing feedbacks could push the Earth System toward a planetary threshold that, if crossed, could . . . cause continued warming on a "Hothouse Earth" pathway even as human emissions are reduced'. While this assessment is characterized by multiple and unavoidable uncertainties, it points to the profound long-term implications for peace and stability of changes in the biosphere and climate system.

How are we doing in moving towards a safe and just space for humanity? Merging planetary boundaries with aspirational social goals frameworks

Planetary boundaries propose the outer limits of pressure that humanity should place on critical Earth systems in order to protect human well-being. Yet at the same time, human well-being also depends on each person having access to the resources needed to meet the requirements for a good quality of life. This thinking builds on a human needs-based approach to defining and measuring social outcomes (Doyal and Gough 1984, Christie 1997). Human needs theory argues that there are a finite number of basic human needs that are universal, satiable and non-substitutable. 'Need satisfiers' can vary between individuals and cultures, but arguably have certain universal characteristics that may be measured empirically.

Kate Raworth developed the safe and just space (SJS) framework by combining the concept of planetary boundaries with the complementary concept of social boundaries (Raworth 2017). It visualizes sustainability in terms of a doughnut-shaped space where resource use is high enough to meet people's basic needs (the inner boundary), but not so high as to transgress planetary boundaries (the outer boundary). The SJS framework includes 11 social objectives, which were selected by Raworth based on a comprehensive text analysis of government submissions to the United Nations Conference on Sustainable Development (Rio+20) in 2012. The objectives reflect the main social goals mentioned in the majority of submissions, and thus align well with contemporary policy, including the social objectives in the UN's Sustainable Development Goals (SDGs).

Combining the inner limits of social boundaries and the outer limits of planetary boundaries in this way creates a space within which all of humanity can thrive by pursuing a range of possible pathways that could deliver inclusive and sustainable development. This framework makes clear one of humanity's major challenges in the 21st century: to ensure that use of the Earth's resources achieves the human rights of all—7 billion people, rising to at least 9 billion—while simultaneously ensuring that the total pressure on Earth systems remains within planetary boundaries. Recent work by O'Neill et al. (2018) developed indicators designed to measure a 'safe and just' development space, by quantifying the resource use associated with meeting basic human needs and comparing this to downscaled planetary boundaries for over 150 nations. They found that no country meets the basic needs for its citizens at a globally sustainable level of resource use, and that meeting the basic needs of all people on the planet would result in humanity transgressing multiple environmental limits, based on current relationships between resource use and human well-being.

While the SJS framework aims to specify the social and planetary boundaries between which humanity can thrive, it does not suggest specific pathways for getting into that safe and just space. The precise configuration of the space will depend on the scale and boundary definitions chosen. There are likely to be many possible pathways in that space, which will be aligned with different cultures, visions and values, and with different costs, risks, and distributions of power and benefits between social groups. So, there will be a range of outcomes for social justice. This makes the process of adjudicating between them a deeply political one (Leach et al. 2018).

Enter the Anthropocene: The Great Acceleration

The Great Acceleration: Trends and implications

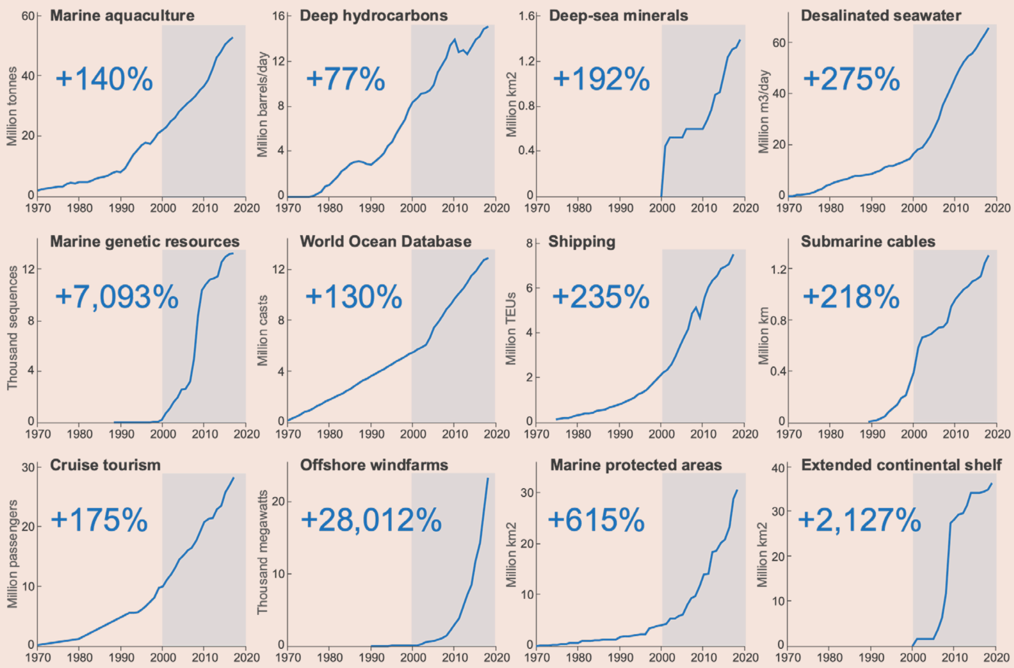
There is growing scientific recognition that we live in an epoch where humans have become a dominant force of planetary change—termed the Anthropocene (Steffen et al. 2007). Debates about the precise point in history that signifies the advent of the Anthropocene rage on (Subramanian 2019). However, one strong candidate has emerged from work led by the International Geosphere-Biosphere Programme (IGBP), which synthesized research on socio-economic trends from 1750–2010 using 12 indicators associated with human activity. Another 12 indicators were used to represent variables critical to Earth system structure and functioning, including atmospheric composition, stratospheric ozone, the climate system, the water and nitrogen cycles, marine ecosystems, land systems, tropical forests and terrestrial biosphere degradation. Based on the globally aggregated data sets, the trends show a sharp increase after approximately 1950, which has become popularly known as the 'Great Acceleration' (Steffen et al. 2007).

All of the results were updated in 2015 (Steffen et al. 2015a) and more details were added with regards to differentiating between the contributions that different countries made to these trends. The key point here being that while all humans on the planet are impacted by the trends, not all are driving them equally. The results show the ways in which a small portion of the population is affecting the planet, at its global scale. Over the past two centuries, the human population, the economic wealth *of some of that population* and inequality—which is obviously masked by looking at globally aggregated data sets—have all grown rapidly.

The first two factors are often described as resulting in increased resource consumption, as demonstrated by trends in agriculture and food production, forestry, industrial development, transport and international commerce, energy production and urbanization. Indeed, all of these factors show an abrupt and dramatic rise in the latter part of the 20th century. Telecommunications, tourism and foreign direct investment—useful as proxies for tracking the growth of globalization—show a later dramatic increase, with the change occurring in the 1990s. Below, we unpack some of the key indicators and their trends through the Great Acceleration.

Some trends do show signs of slowing, but the changes are due to different reasons. For instance, the stratospheric ozone (measured in percentage loss) appears to be stabilizing, in part due to international efforts through the Montreal Protocol. Marine fish capture is also declining but as the result of declining wild fish and the need to shift to aquaculture, which shows a corresponding rise. While the Great Acceleration has a few relevant indicators for marine systems, additional work specific to the 'Blue Acceleration' (see box 2.1) has explored the combination of climate impacts and expanding human activity within, or impacting on, marine ecosystems (Jouffray et al. 2020). Trends show similar patterns of rise to the Great Acceleration, although often with a time lag as activities on land later shift to activities within oceans. In terrestrial systems, what appears to be the beginning of a stabilizing trend for the conversion of land to human use in the last 60 years is likely due to agricultural intensification. While the transition from extensive to intensive agriculture has allowed for higher yields in less land, which explains the stabilizing trend, this has been at the expense of a steep increase in the use of artificial inputs that led to severe environmental degradation and biodiversity loss (Rist et al. 2014, IPBES 2019).

Box 2.1. The Blue Acceleration: Our dash for ocean resources mirrors what we have already done to the land



In 2019, researchers from the Stockholm Resilience Centre at Stockholm University synthesized 50 years of data from shipping, drilling, deep-sea mining, aquaculture, bioprospecting and much more. They found clear signals of a 'Blue Acceleration'—a recent and dramatic acceleration of human pressure on the world's ocean, which began at the start of the 21st century and shows no sign of slowing down (Jouffray et al. 2020).

Rising demand for fresh drinking and irrigation water, for example, means there are now 16 000 desalination plants worldwide, which transform 65 million cubic metres of seawater per day, with rapid growth predicted for floating plants. They suck in and kill small marine life and discharge warm, highly salty water that can disrupt coastal ecosystems.

Meanwhile, there are more than 1.3 million kilometres of undersea telecommunications cables and more than 100 000 km of seabed pipelines carrying gas, oil, water or sewage. These are innocuous unless they leak after damage from anchors or storms, but they are incompatible with some other seabed activities, such as dredging for sand.

Demand for fish—wild and farmed—is soaring worldwide and is projected to reach 154 million tonnes by 2030. There is also the $385 billion nutraceutical market, which, for example, exploits the small crustacean krill for omega-3 fatty acids. Millions of marine organisms are used each year for home decorations, jewellery and aquaria. Bioprospecting for ingredients for medicines, cosmetics or other chemicals is also increasing.

The 'Blue Acceleration' is having major social and ecological consequences, often at odds with the rhetoric of a sustainable and equitable blue economy that was put forward at the United Nations Conference on Sustainable Development (Rio+20) in 2012. Exploitation of the ocean has tended to precede exploration, and while the ocean is vast, it is not limitless. Serious concerns exist about potentially unsustainable growth trajectories and systemic inequity in the current ocean economy. Access to ocean resources and the financial and technical capacity to engage in the full range of ocean sectors are inequitably distributed. The majority of benefits are accrued by a small portion of the global population, while the majority of harms, including from climate change impacts, are falling on the most vulnerable.

Equity dimensions in the Anthropocene

There are many forms of inequalities and inequities that affect, and are affected by, the biosphere in various ways and these relationships will play a key role on the human capacity to face the new dynamics of the Anthropocene (see the following two subsections). Equity dimensions are commonly divided into three categories: distributional equity, recognitional equity and procedural equity (Leach et al. 2018). Distributional equity refers to the distribution of resources, costs and benefits among people. Recognitional equity refers to recognition of interest holders and respect for identity, values and associated rights. Procedural equity relates to how decisions are being made. It thereby draws on theories about law, institutions, governance and participation, and how groups and various interests are represented or have authority in decision making. These three categories can then be set in the context of equity of what (including opportunities, rights and access) and among whom (including e.g. class, gender and ethnicity). The latter is also related to the distinction between vertical and horizontal inequality (Stewart 2016). Vertical inequalities are inequalities between all the people in a given group, for example, in the form of incomes or educational attainment. Horizontal inequalities are inequalities between groups that share similar characteristics, for example, ethnicity or gender. Finally, a cross-cutting dimension to all these aspects or forms of equity is the fact that these dimensions can both be intra- and inter-generational, the latter being particularly important to environmental sustainability (Spijkers 2018).

Effects of the biosphere on inequality

Inequality is affected both by geographical and biophysical preconditions, as well as changes in the biosphere and climate system in different ways. For example, different parts of the world differ in terms of the potential for agriculture, water availability for drinking and irrigation, the availability of minerals and metals, forest resources and other forms of natural capital or ecosystem services/NCPs (Scheffer et al. 2017, Managi 2018). Even in parts of the world where these resources are available, there are often substantial differences in the access to them among different groups in society. Environmental risks also differ between countries, regions and social groups. In many parts of the world, people with lower levels of income and education are often more exposed to the prevalent environmental risks than others. They may live in areas that are more exposed to environmental risks and have lower coping and adaptive capacity to navigate and recover from environmental shocks (Queiroz et al. forthcoming). The reasons for this are multiple and range from an unawareness of the risks, many times perpetuated by unsustainable practices or livelihood choices, to forced displacements into more vulnerable areas due to conflict, or the lack of alternatives due to insufficient economic and material means to invest in prevention and recovery after disasters. For example, extreme weather and climate-related disasters such as heatwaves and storms have killed more than 410 000 people in the last decade, most of them in low income and lower mid-income countries (IFRC 2020). In West Africa, climate change has become a 'threat multiplier' in regions that are already vulnerable and/or fragile (Krampe 2019). In the Sahel region, several climate-related trends such as the increased intensity and duration of droughts and desertification are having disproportional impacts on the livelihoods of the most vulnerable, who depend on local natural resources (Mbaye 2020). In the same region, the existing trends of violent conflict have led to the displacement of millions of people, exacerbating pre-existing environmental degradation in host sites and likely leading to further loss of resilience in both displaced and host communities. Inequalities thus imply both risks and vulnerabilities for the less wealthy, who tend to be hit the hardest by environmental shocks, progressively eroding their resilience and contributing to the exacerbation of inequalities (Hamann et al. 2018).

Creeping changes in biosphere conditions also affect inequality. For example, climate change does not only lead to increased global mean temperatures, but also has huge impacts on marine species that are of great importance for food security. Modelling work shows that potential catches of marine fisheries are likely to shift dramatically across regions in the world. As oceans become warmer and more acidic, countries in South East Asia and West Africa can expect considerable reductions in the future maximum potential catch. The opposite holds for fisheries in wealthier regions like Northern Europe (Sumaila et al. 2011). By drawing on the most recent data related to the impacts of climate change on marine fisheries, Blasiak et al. (2017) show that the vulnerability to changes in fish stocks due to climate change is highest in Small Island Developing States and Least Developed Countries. Impacts on fisheries, tend to go hand in hand with impacts on terrestrial crop yields, thus resulting in possible cascading shocks as abrupt changes in the world's oceans could drive further changes in scarce land-based resources.

Thiault et al. (2019) elaborate this issue by combining climate models with global employment, economic and food security data and assess the potential effects of climate change on two key food sectors: agriculture and fishing. Their findings show that 90 per cent of the global population may face decreases in productivity for both agriculture and fishing if greenhouse emissions are not reduced; but more worryingly, the same countries that are vulnerable to changes in fisheries are also vulnerable to agriculture changes due to climate change.

Effects of inequality on the biosphere

The causality also goes the other way: increased inequality can cause changes in the biosphere and the climate system (Hamann et al. 2018). Inequality can be a driver of behaviour in combination with individual aspiration to adhere to social norms and copy the behaviours of those that are seen as more successful (Genicot and Ray 2017). If those seen as more successful are behaving in ways that are environmentally harmful (depending on the context, this may entail overconsumption of luxury goods or having a meat-intensive diet), this could make others in society aspire to the same behaviour—creating a cycle of environmentally harmful behaviours (Hamann et al. 2018). It has been suggested that having monetary wealth concentrations in the hands of a few changes investment patterns in ways that contribute to tropical deforestation, thereby contributing to the loss of ecosystems' functions (Ceddia 2020). Inequalities of voice and power have also been linked to corruption in sectors associated with the extraction of natural resources, including the violation of human rights and violence against defenders of the environment (Butt et al. 2019).

Inequalities also affect cooperation in sustaining local environmental commons. Empirical evidence shows that horizontal inequality in terms of ethnicity or class hinders cooperation and collective action by pitting groups against each other (Hamann et al. 2018). Conversely, in cases of resource-rich areas, local individuals also have a high stake and vested interests in the common, and evidence indicates that in such cases increasing inequality may increase cooperation (Hamann et al. 2018). Theoretical predictions in fisheries suggest that a high market concentration in relation to a fish stock may increase the likelihood of cooperation if those with market power also have a long-term interest in keeping a flourishing fish stock (Beddington et al. 2007). In such cases, powerful actors may prefer to decrease harvest rates in order to increase the stock.

However, as increases in market concentration often tend to be coupled with high profits for market actors, the power of such actors may result in pressure to continue and increase wealth accumulation and power that is not to the benefit of the greater good of society—rather, the opposite (Leach et al. 2018). On the one hand, it has been proposed that more direct engagement with the small number of large transnational corporations that currently dominate agriculture, forestry and fisheries could leverage their market dominance to help drive supply chains towards more sustainable production behaviours (Österblom et al. 2015, Folke et al. 2019). On the other hand, demands on these corporations to deliver continuous profit could undermine the business case for corporate sustainability (Clapp 2015, 2021).

Human impacts on the Earth system and biosphere since the Great Acceleration

Climate change: Trends and implications

Climate science has made impressive advancements in the last decades in exploring the dynamics of the climate and Earth system, and the risks entailed with a changing climate.

As the work advanced by the Intergovernmental Panel on Climate Change (IPCC) has shown, it is becoming increasingly clear that human activities, even during the economic slowdown resulting from the Covid-19 pandemic, are driving rapid increases in concentrations of greenhouse gases and as a result also in global mean temperatures (IPCC 2014, Quéré et al. 2021). In addition, the health crises created by the pandemic have intersected with extreme events triggered by a changing climate, resulting in what some have called 'compound climate risks' (Phillips et al. 2020).

One key result from the recent synthesis by the World Meteorological Organization (WMO), the IPCC and others (WMO 2019) is that 'climate impacts are hitting harder and sooner than climate assessments indicated even a decade ago' (p. 5), putting both ecosystems and people at risk due to the risk of crossing critical tipping points. Accelerated sea level rise, ocean acidification, the continued decrease of sea ice and ice masses, and increasing extreme weather events such as heatwaves, wildfires and cyclones all point to the visible impacts of climate change already today. As the IPCC has elaborated in detail (IPCC, 2018), the difference for people and nature between 1.5 degrees Celsius and 2°C global warming are considerable. These include differences in mean temperature both on land and in oceans, hot extremes in most inhabited regions, heavy precipitation in several regions, and the probability of drought (IPCC, 2018, p. 9).

Unfortunately, a recent report issued by the WMO (WMO 2020) indicates that there is a 40 per cent chance that the annual average global temperature will temporarily reach 1.5°C above the pre-industrial level (the target set as a global ambition in the Paris Agreement) in at least one of the next five years. As the WMO notes, this means that the next few years are likely to be the warmest on record, with numerous cascading effects on extreme weather events, such as tropical cyclones, and changes in precipitation patterns, to mention just a few.

Biodiversity Loss: Trends and implications

Over a relatively short time in history (the past 50 years), human population has doubled, the global economy has grown nearly fourfold and global trade has grown tenfold. While this has contributed to new economic opportunities, it has also led to massive impacts on biodiversity and the Earth's ecosystems. The recent Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) global assessment report on biodiversity and ecosystem services (IPBES 2019) showed that an average of around 25 per cent of species in assessed animal and plant groups are threatened, suggesting that around 1 million species already face extinction—many within decades—unless action is taken to reduce the intensity of drivers of biodiversity loss. Without such action, there will be a further acceleration in the global rate of species extinction, which is already at least tens to hundreds of times higher than it has averaged over the past 10 million years.

On average, large terrestrial mammals have been extirpated from 75 per cent of their natural ranges (IPBES 2019) and over 60 per cent of vertebrate animal populations have been lost since the 1970s (WWF 2020). In fact, today, the biomass of humans and domesticated animals (cattle, pigs and poultry) far surpasses the biomass of wild mammals. Recent estimates suggest that in terms of biomass, 60 per cent of all mammals living on the planet are livestock, 36 per cent are humans and only 4 per cent are wild species (Bar-On et al. 2018).

One of the most significant impacts of these overall declines in diversity (species, habitats, forests, etc.) is an increasingly homogenized biosphere. Globally, local varieties and breeds of domesticated plants and animals are disappearing. This loss of diversity, including genetic diversity, poses a serious risk to global food security by undermining the resilience of many agricultural systems to threats such as pests, pathogens and climate change. For example, as a direct result of crop homogenization and increased pesticide and herbicide use, there has been an estimated 40 per cent loss of insects (Sánchez-Bayo and Wyckhuys 2019), which results in a steep pollination decline (Klein et al. 2007, IPBES 2016). As 75 per cent of crops used for human food consumption are, at least to some degree, dependent on insect pollination, we can expect severe negative impacts on food production. Already now, pollinator loss risks $235–577 billion in global crop output annually (IPBES 2016, 2019). Many hotspots of agrobiodiversity and of crop wild relatives are also under threat or lack formal protection, jeopardizing the pool of genetic variation that underpins the long-term resilience of agricultural production and food systems in the face of environmental change.

Land use change: Trends and implications

Land conversion to agriculture is the most important driver of land use change and decline of natural habitats such as forests, wetlands and rangelands (IPBES 2019). Studies have shown that nearly 40 per cent of all productive land on the Earth's surface is used for agriculture (Foley et al. 2011). About 30 per cent of the world's forests are considered to be permanently lost and deforestation and forest degradation are continuing to increase at alarming rates (FAO 2020). Alongside the detrimental consequences to biodiversity (80 per cent of the world's terrestrial biodiversity depends on forest habitats) and climate mitigation (forests are one of the main terrestrial carbon sinks), deforestation poses a major threat to the livelihoods of 1.6 billion people globally, one million of whom are among the most vulnerable people (IUCN 2021).

Land use change shows significant regional differences and the global trends presented above can be unequally distributed across the planet. For example, deforestation trends are mainly increasing in the Global South, driven by international food trade and the consequent conversion of tropical forests to the production of beef, sugar cane, soyabeans, oil palm and cocoa (Winkler et al. 2021). In contrast, forest gains, driven by, for example, afforestation policies (such as in the case of China) or agricultural land abandonment (such as in the case of Europe) (Queiroz et al. 2014, Winkler et al. 2021) have been the predominant trend in the Global North during the last decades.

Soil erosion, which is mainly driven by loss of plant cover, is a slow form of land degradation that has profound, and many times permanent, impacts on biogeochemical cycles and land productivity, along with still poorly quantified potential impacts on climate change (Borrelli et al. 2017). About 75 billion tonnes of soil are eroded every year from cultivated lands worldwide, with an estimated financial loss of $400 billion per year. If current rates of soil loss continue, the future of farming and millions of agricultural livelihoods around the world are at risk. Soil is also the biggest store of terrestrial carbon. Land degradation in all its forms affects the levels of organic carbon in the soil, and croplands can lose 50 per cent or more of their organic carbon compared with natural habitats (IPBES 2019). Loss of organic carbon in the soil has severe impacts on climate, soil water and nutrient retention capacity, and soil biodiversity.

The above dynamics also capture why agriculture is one of the key drivers of climate change, contributing to at least 25 per cent the total greenhouse gas emissions. At the same time, food and agricultural systems will be largely impacted by these trends (IPCC 2019). For example, climate change can alter the relationships among crops, pests, pathogens and weeds. Moreover, it might exacerbate trends such as declines in pollinating insects, increasing water scarcity and increasing concentrations of ground-level ozone (Myers et al. 2017), and some of these consequences are already being felt in vulnerable parts of the world.

Oceans: Trends and implications

Marine ecosystems, from coastal to deep sea, have been hugely influenced by human actions, with coastal marine ecosystems displaying large historical losses in both extent and condition, as well as rapid ongoing declines. Studies show that over 40 per cent of the ocean area was strongly affected by multiple human drivers in 2008, and that 66 per cent has been experiencing increasing cumulative impacts since then (Halpern et al. 2015, 2019). Live coral cover on reefs has nearly halved in the past 150 years, and the decline has dramatically accelerated over the past two or three decades due to increased water temperature and ocean acidification interacting with and further exacerbating other drivers of loss (Gardner et al. 2003, Bruno and Selig 2007, Hughes et al. 2010). Similarly, global assessments have found that seagrass beds have been disappearing at a rate of 110 km^2 per year since 1980 and that 29 per cent of the known areal extent has disappeared since seagrass areas were initially recorded in 1879 (Waycott et al. 2009). Coastal marine ecosystems, such as coral reefs and seagrass beds, are among the most productive systems globally, and their loss and deterioration reduce their ability to protect shorelines, and the people and species that live there, from storms, as well as their ability to provide sustainable livelihoods.

The severe impacts on ocean ecosystems are also illustrated by 33 per cent of fish stocks being classified as overexploited and greater than 55 per cent of the ocean area being subject to industrial fishing (Pauly et al. 2003, Worm et al. 2009). Recent assessments by Hilborn et al. (2020), have found that, in some areas, management efforts are leading to improving stock abundance. However, in many places, these same trends do not hold. Moreover, management efforts are being undermined by illegal, unreported and unregulated exploitation of fisheries and the conflicts that often emerge in response (Pomeroy et al. 2007, Spijkers et al. 2019). These combined pressures are reducing the resilience of ocean ecosystems—or their ability to remain productive in the face of shocks and disturbances.

Furthermore, oceans function as huge carbon sinks and absorb about a quarter of the carbon dioxide that humans put into the air, primarily through the burning of fossil fuels (Gattuso et al. 2015). This carbon dioxide has caused accelerated acidification in the oceans, currently occurring at a rate not seen on Earth for over 50 million years (Nagelkerken and Connell 2015), with severe impacts on ocean health, marine biodiversity and those who depend on it for their livelihoods and well-being. Acidification reduces the ability of animals to calcify and make their own shells, and threatens marine ecosystems such as coral reefs (Pandolfi et al. 2011). This acidification trend is combined with trends in fertilizer use from intensive agriculture. Dead zones can be caused by fertilizer run-off and they are increasing in number and growing in scale around the world (Diaz and Rosenberg 2008, Altieri and Gedan 2015). Climate change is also driving the long-term persistent warming of the global ocean that has been occurring over the past century, with far-reaching implications for marine ecosystems. Concurrent with this, discrete periods of extreme regional ocean warming (marine heatwaves, MHWs) have increased in frequency (Oliver et al. 2018). These MHWs have deleterious impacts across a range of biological processes and taxa, including critical foundation species (corals, seagrasses and kelps), and have the capacity to restructure entire ecosystems and disrupt the provision of ecological goods and services in coming decades (Smale et al. 2019).

Risk and turbulence in the Anthropocene

Regime shift trends and implications

Human changes to the biosphere are increasing the occurrence of regime shifts—large, abrupt and persistent critical transitions in the function and structure of social-ecological systems (Scheffer et al. 2001, Biggs et al. 2012a, Hughes et al. 2013). Evidence of such shifts can be found in multiple social-ecological systems and at multiple geographical scales, from the local (e.g. a lake) to the global (e.g. the Earth system). Many of these shifts are also associated with loss of key ecosystem services that underpin livelihoods, economic activities and human development (Rocha et al. 2014).

The regime shift concept has its roots in catastrophe theory, an area of dynamical systems theory that analyses abrupt changes in system behaviour. Similar, and related, dynamics and concepts have been applied and further developed in disciplines such as ecology, physical oceanography and climate science. 'Tipping elements' (TEs) in the climate system are a good illustration of this. These include melting sea ice and Greenland and Antarctic ice sheets, changes in ocean and atmospheric circulation, and loss or alteration of critical biomes such as the large forests in the Amazon region and boreal forests in Russia and Canada (Lenton et al. 2019). Many of these regions and processes are changing rapidly because of human pressures, such as through deforestation induced by expanding soy plantations (Amazon) or paper production (boreal forests). Human activities and the Great Acceleration are rapidly changing the internal dynamics and driving feedbacks of TEs, with subsequent effects on the stability of the climate system as a whole (Steffen et al. 2018).

The precise impacts of such abrupt shifts on people and their well-being are difficult to summarize briefly due to social, economic and ecological uncertainties, complex interactions, and their context dependence. In addition, domino effects between different abrupt changes in the climate and ecosystems could have large, yet unquantifiable, impacts on livelihoods in land- and seascapes (Rocha et al. 2018). These connections between human, ecological and technical systems, and the associated possibility of cascading failures, can in some regards be seen as systemic risks prone to 'normal accidents' that emerge in surprising ways, thus seriously challenging the capacity of institutions and communities to respond quickly (Galaz et al. 2011) (see the following section for more details).

Exploring such impacts requires the definition of at least the following dimensions: the social-ecological system of interest (e.g. coastal ecosystems, a coral reef ecosystem or agricultural landscapes); geographical scale (e.g. local, regional or global); and the temporal scale (short-term, decadal or even millennial). For example, deforestation in the Brazilian Amazon and Cerrado linked to abrupt shifts in precipitation patterns could seriously affect maize yields, with severe food security implications in the Latin American region (Spera et al. 2020). Thresholds in agro-ecosystems and water availability can threaten productivity and a suite of ecosystem services in irrigated and rainfed agriculture, even in industrialized countries (Gordon et al. 2008). Climate feedbacks driving the world towards high-end climate scenarios (Steffen et al. 2018) could lead to very large stresses on people, especially in tropical regions, potentially forcing between one and three billion (if other adaptation options are unavailable) to migrate by 2070 (Xu et al. 2020).

Abrupt and practically irreversible changes are not limited to biophysical and ecological systems, however, as they also affect social systems, including shifts in values and mental models (Milkoreit et al. 2018, Otto et al. 2020).

Box 2.2. Zoonotic disease as an Anthropocene risk

Human development, health and environmental change are closely related. As a number of syntheses have noted in recent years, climate change is likely to have numerous repercussions on human health all over the world both through direct and indirect effects (Watts et al. 2017). Land-use change, climate change, and the loss of biodiversity and ecosystem services interact in ways that endanger the health and well-being of people by increasing the exposure to infectious disease (Jones et al. 2008, Marco et al. 2020), water scarcity, food scarcity, natural disasters, and population displacement (Myers and Patz 2009). Zoonotic diseases are significant threats to human health, with vector-borne diseases accounting for approximately 17 percent of all infectious diseases and causing (before the Covid-19 pandemic) an estimated 700 000 deaths globally per year (Díaz et al. 2019, IPBES 2019). Already today, millions of people die from illnesses that could have been treated with access to care—whether bacterial, viral or other diseases. Among them are hundreds of thousands of people who die from diseases caused by antibiotic-resistant bacteria, parasites and fungi (Laxminarayan et al. 2016).

The Covid-19 pandemic, with its impacts on human health, food security and economic stability all over the world, clearly shows why such new health risks can no longer be ignored. While assessments of the economic impacts of pandemics have been made several times by international agencies (Jonas 2014), the economic and human development impacts of the still unfolding Covid-19 pandemic show an ever bleaker picture: larger losses in global gross domestic product (–5.2 per cent for 2020) and the expectation 'to plunge most countries into recession in 2020, with per capita income contracting in the largest fraction of countries globally since 1870'. Needless to say, the most vulnerable are the worst affected by these economic impacts, with increases in the extreme poverty rate and the number of extreme poor, and seriously affecting over a billion men and women in the informal economy (Lee et al. 2020).

Therefore, understanding the drivers of increased disease risks such as zoonoses is of fundamental importance. Loss of forest cover, construction of water systems, urbanization and demographic change have been proven to spawn zoonotic pathogens, which are a significant cause of emerging and re-emerging infectious diseases, such as coronaviruses, avian influenzas and the West Nile virus (Wilkinson et al. 2018). However, infectious disease risks are dynamic and subject to multiple and complex drivers. For example, vector-borne infectious disease risks are affected by not only changing temperatures, but also sea level rise. The geographical distribution of African trypanosomiasis is predicted to shift due to temperature changes induced by climate change. Biodiversity loss may lead to an increase in the transmission of infectious diseases such as Lyme disease, schistosomiasis, hantavirus and West Nile virus. New estimates also indicate that increasing temperatures could expose more than 1.3 billion new people to the risk of Zika virus by 2050. Further, the overuse of antibiotics is driving the rapid evolution of antibiotic resistance in many bacterial pathogens (Jørgensen et al. 2018).

Turbulence and risk in the Anthropocene

The Anthropocene is hyperconnected. Human migration, international trade, transnational land acquisitions, spread of invasive species and technology diffusion occur at unprecedented scales, underpinned by a global infrastructure that facilitates the movement of people, goods, services, diseases and information (Reid et al. 2010). Actions taken in seemingly independent places increasingly affect interlinked global social–ecological systems in unexpected ways, with surprising mixes of immediate consequences, as well as cascading and distant effects. Such connections can be a force for good. For example, remittances can help families cope with a suite of problems in troubling times (Adger et al. 2002). Global information and communication technologies have proven critical to helping coordinate national responses and facilitate information sharing between scientists during the Covid-19 pandemic. Further, both local and national resilience to food scarcity and shocks have been shown to be partly supported by the international food trade (Porkka et al. 2013). These connections have also laid the foundation for highly complex global supply chains and corporate networks, in some sectors dominated by a handful of transnational corporations, which underpin global production and consumption (Folke et al. 2019).

The flip side is that the hyperconnectivity increases the chances that small, local failures in a system (e.g. a disease outbreak) escalate into global systemic risks (see box 2.2). For instance, when a disease outbreak becomes—through air travel—a global epidemic, with impacts on global health and with widespread consequences for businesses and economies worldwide. Systemic risks describe situations where a crisis or shock in one domain, such as ecosystem health, can increase risk in an unbounded number of interdependent domains, such as our global climate, food and water supplies, and energy and financial systems (Galaz et al. 2011, Helbing 2013, Centeno et al. 2015). They stem from interactions at the interface of multiple systems (e.g. climatic, ecological, political, financial and technological), making it hard to identify causes and to foresee outcomes.

There is a growing interest in those risks that have a clear environmental or ecological dimension, such as climate change, deforestation, extreme weather events or natural resource constraints. Some authors have suggested moving beyond the notion of systemic risks and instead speaking of

Anthropocene risks (Keys et al. 2019). One illustrative example of a systemic Anthropocene risk is how the more efficient use of water in one area of the world can have massive consequences on rainfall in another region. This is, for instance, the case in hydrological teleconnections that link evaporation rates in one part of the world to the precipitations in other. For example, agricultural intensification in India influences rainfed agriculture in East Africa. The situation presents a delicate dilemma: if communities in India improve sustainable agriculture practices (reduced irrigation and groundwater depletion), this could reduce the supply of water that evaporates and lead to a significant depletion in East African rainfall, with corresponding consequences for the productivity of local ecosystem services, such as water for animals, agriculture, trees and more. Such an interruption in rainfall could also have regional impacts: it might trigger migration and lead to conflict over the distribution of resources. Another related issue is the risk of current land use homogenization leading to the homogenization of the terrestrial water cycle, with severe consequences for planetary resilience (Levia et al. 2020).

The global food system is also part of emerging systemic Anthropocene risks (Nyström et al. 2019). As food systems become increasingly interconnected and globalized (about one quarter of all food production for human consumption is traded internationally (D'Odorico et al. 2014), the effects of these drivers can create synchronous shocks across different regions and sectors. In tandem with the massive growth of international trade there has been an increase in connections between different food production sectors. For example, the aquaculture sector, which has traditionally relied heavily on wild-caught fish as the main source for feed, is shifting towards crop-based feed (e.g. soy, rapeseed and maize) in response to declining fish catches (Troell et al. 2014). This increased dependence of aquaculture on crops makes seafood production vulnerable to droughts or crop pest outbreaks on land. Similarly, the collapse of fish stocks traditionally used in feed has driven an increasing demand for soya and other feed crops at the expense of crops for direct human consumption, leading to rising food prices, decreasing food exports and, consequently, food shortages in distant developing countries dependent on food imports (Seekell et al. 2017, Cottrell et al. 2019). Moreover, food production systems around the world are increasingly exposed to the price fluctuations of inputs (e.g. fossil fuels, fertilizers and technology); shifts in global consumer preferences (e.g. diets); changes in policies (e.g. regulations on energy and exports); and financial speculation in food commodities. Recent food price spikes in 2008 and 2010 provide an illustration of how energy prices, connected food production systems and financial markets triggered shocks to societies and places around the globe, with vast multisystem impacts on individuals, communities and political systems (including food riots and violence in dozens of countries, e.g. Bangladesh, Burkina Faso, Cameroon, Egypt, Indonesia and Yemen) (Biggs et al. 2011).

Such risks and their impacts on human development are difficult to quantify with greater precision due to their multilevel and complex system properties. In such contexts, understanding the social and ecological factors that avoid maladaptation and instead enhance resilience—such as response diversity, redundancy and adaptive modes of governance—become essential (Biggs et al. 2012b). Hence, the impacts of a changing planet on human development will not only depend on changes in frequencies of shocks (such as droughts, floods and extreme weather events), but also the anatomy of connectivity across systems (such as land, oceans and climate), as well as the brittleness of important biomes and ecosystems underpinning human development. A recent synthesis by Rocha et al. (2018) based on 300 case studies and a review of more than 1000 academic papers is an example of the former. This study showed that abrupt catastrophic shifts (known as 'regime shifts' in the literature) in one biome or ecosystem can trigger similar irreversible shifts in other biomes, sectors and/or regions.

Key references

Adger, W. N., P. M. Kelly, A. Winkels, L. Q. Huy, and C. Locke. 2002. Migration, Remittances, Livelihood Trajectories, and Social Resilience. *AMBIO: A Journal of the Human Environment* 31(4):358–366.

Altieri, A. H., and K. B. Gedan. 2015. Climate change and dead zones. *Global Change Biology* 21(4):1395–1406.

Bar-On, Y. M., R. Phillips, and R. Milo. 2018. The biomass distribution on Earth. *Proceedings of the National Academy of Sciences* 115(25):6506–6511.

Beddington, J. R., D. J. Agnew, and C. W. Clark. 2007, June 22. Current problems in the management of marine fisheries. American Association for the Advancement of Science.

Biggs, D., V. Dakos, R. J. Scholes, and M. Schoon. 2011. Are We Entering an Era of Concatenated Global Crises? 16(2).

Biggs, R., T. Blenckner, C. Folke, L. Gordon, A. Norström, M. Nyström, and G. Peterson. 2012a. Regime Shifts. Pages 609–617 *in* A. Hastings and L. Gross, editors. *Sourcebook in Theoretical Ecology*. University of California Press.

Biggs, R., M. Schlüter, D. Biggs, E. L. Bohensky, S. BurnSilver, G. Cundill, V. Dakos, T. M. Daw, L. S. Evans, K. Kotschy, A. M. Leitch, C. Meek, A. Quinlan, C. Raudsepp-Hearne, M. D. Robards, M. L. Schoon, L. Schultz, and P. C. West. 2012b. Toward Principles for Enhancing the Resilience of Ecosystem Services. *Annual Review of Environment and Resources* 37(1):421–448.

Blasiak, R., J. Spijkers, K. Tokunaga, J. Pittman, N. Yagi, and H. Österblom. 2017. Climate change and marine fisheries: Least developed countries top global index of vulnerability. *PLOS ONE* 12(6):1–15.

Borrelli, P., D. A. Robinson, L. R. Fleischer, E. Lugato, C. Ballabio, C. Alewell, K. Meusburger, S. Modugno, B. Schütt, V. Ferro, V. Bagarello, K. Van Oost, L. Montanarella, and P. Panagos. 2017. An assessment of the global impact of 21st century land use change on soil erosion. *Nature Communications* 8(1):2013.

Bruno, J. F., and E. R. Selig. 2007. Regional decline of coral cover in the Indo-Pacific: Timing, extent, and subregional comparisons. *PLOS ONE* 2(8):e711.

Butt, N., F. Lambrick, M. Menton, and A. Renwick. 2019. The supply chain of violence. *Nature Sustainability* 2(8):742–747.

Ceddia, M. G. 2020. The super-rich and cropland expansion via direct investments in agriculture. *Nature Sustainability* 3(4):312–318.

Centeno, M. A., M. Nag, T. S. Patterson, A. Shaver, and A. J. Windawi. 2015. The Emergence of Global Systemic Risk. *Annual Review of Sociology* 41(1):65–85.

Christie, D. J. 1997. Reducing direct and structural violence: The human needs theory. *Peace and Conflict: Journal of Peace Psychology* 3(4):315–332.

Clapp, J. 2015. Distant agricultural landscapes. *Sustainability Science* 10(2):305–316.

Clapp, J. 2021. The problem with growing corporate concentration and power in the global food system. *Nature Food* 2(6):404–408.

Cottrell, R. S., K. L. Nash, B. S. Halpern, T. A. Remenyi, S. P. Corney, A. Fleming, E. A. Fulton, S. Hornborg, A. Johne, R. A. Watson, and J. L. Blanchard. 2019. Food production shocks across land and sea. *Nature Sustainability*.

D'Odorico, P., J. A. Carr, F. Laio, L. Ridolfi, and S. Vandoni. 2014. Feeding humanity through global food trade. *Earth's Future* 2(9):458–469.

Diaz, R. J., and R. Rosenberg. 2008, August 15. Spreading dead zones and consequences for marine ecosystems. American Association for the Advancement of Science.

Díaz, S., U. Pascual, M. Stenseke, B. Martín-López, R. T. Watson, Z. Molnár, R. Hill, K. M. A. Chan, I. A. Baste, K. A. Brauman, S. Polasky, A. Church, M. Lonsdale, A. Larigauderie, P. W. Leadley, A. P. E. van Oudenhoven, F. van der Plaat, M. Schröter, S. Lavorel, Y. Aumeeruddy-Thomas, E. Bukvareva, K. Davies, S. Demissew, G. Erpul, P. Failler, C. A. Guerra, C. L. Hewitt, H. Keune, S. Lindley, and Y. Shirayama. 2018. Assessing nature's contributions to people. *Science* 359(6373):270–272.

Díaz, S., J. Settele, E. S. Brondízio, H. T. Ngo, J. Agard, A. Arneth, P. Balvanera, K. A. Brauman, S. H. M. Butchart, K. M. A. Chan, A. G. Lucas, K. Ichii, J. Liu, S. M. Subramanian, G. F. Midgley, P. Miloslavich, Z. Molnár, D. Obura, A. Pfaff, S. Polasky, A. Purvis, J. Razzaque, B. Reyers, R. R. Chowdhury, Y. J. Shin, I. Visseren-Hamakers, K. J. Willis, and C. N. Zayas. 2019. Pervasive human-driven decline of life on Earth points to the need for transformative change. *Science* 366(6471).

Doyal, L., and I. Gough. 1984. A theory of human needs. *Critical Social Policy* 4(10):6–38.

Elmqvist, T., C. Folke, M. Nystrom, G. Peterson, J. Bengtsson, B. Walker, and J. Norberg. 2003. Response Diversity, Ecosystem Change, and Resilience. *Frontiers in Ecology and the Environment* 1(9):488.

FAO. 2020. *The State of the World's Forests 2020*. FAO and UNEP.

Foley, J. a., N. Ramankutty, K. a. Brauman, E. S. Cassidy, J. S. Gerber, M. Johnston, N. D. Mueller, C. O'Connell, D. K. Ray, P. C. West, C. Balzer, E. M. Bennett, S. R. Carpenter, J. Hill, C. Monfreda, S. Polasky, J. Rockström, J. Sheehan, S. Siebert, D. Tilman, and D. P. M. Zaks. 2011. Solutions for a cultivated planet. *Nature* 478(7369):337–342.

Folke, C., R. Biggs, A. V. Norström, B. Reyers, and J. Rockström. 2016. Social-ecological resilience and biosphere-based sustainability science. *Ecology and Society* 21(3):art41.

Folke, C., Å. Jansson, J. Rockström, P. Olsson, S. R. Carpenter, F. S. Chapin, A.-S. Crépin, G. Daily, K. Danell, J. Ebbesson, T. Elmqvist, V. Galaz, F. Moberg, M. Nilsson, H. Österblom, E. Ostrom, Å. Persson, G. Peterson, S. Polasky, W. Steffen, B. Walker, and F. Westley. 2011. Reconnecting to the Biosphere. *AMBIO* 40:719–738.

Folke, C., H. Österblom, J. B. Jouffray, E. F. Lambin, W. N. Adger, M. Scheffer, B. I. Crona, M. Nyström, S. A. Levin, S. R. Carpenter, J. M. Anderies, S. Chapin, A. S. Crépin, A. Dauriach, V. Galaz, L. J. Gordon, N. Kautsky, B. H. Walker, J. R. Watson, J. Wilen, and A. de Zeeuw. 2019. Transnational corporations and the challenge of biosphere stewardship. *Nature Ecology and Evolution* 3(10):1396–1403.

Galaz, V., F. Moberg, E. K. Olsson, E. Paglia, and C. Parker. 2011. Institutional and political leadership dimensions of cascading ecological crises. *Public Administration* 89(2):361–380.

Gardner, T. A., I. M. Cote, J. A. Gill, A. Grant, and A. Watkinson. 2003. Long-term region-wide declines in Caribbean corals. *Science* 301(5635):958–960.

Gattuso, J. P., A. Magnan, R. Billé, W. W. L. Cheung, E. L. Howes, F. Joos, D. Allemand, L. Bopp, S. R. Cooley, C. M. Eakin, O. Hoegh-Guldberg, R. P. Kelly, H. O. Pörtner, A. D. Rogers, J. M. Baxter, D. Laffoley, D. Osborn, A. Rankovic, J. Rochette, U. R. Sumaila, S. Treyer, and C. Turley. 2015. Contrasting futures for ocean and society from different anthropogenic CO2emissions scenarios. *Science* 349(6243).

Genicot, G., and D. Ray. 2017. Aspirations and Inequality. *Econometrica* 85(2):489–519.

Gordon, L. J., G. D. Peterson, and E. M. Bennett. 2008. Agricultural modifications of hydrological flows create ecological surprises. *Trends in Ecology and Evolution* 23(4):211–219.

Haider, L. J., M. Schlüter, C. Folke, and B. Reyers. 2021. Rethinking resilience and development: A coevolutionary perspective. *Ambio*.

Halpern, B. S., M. Frazier, J. Afflerbach, J. S. Lowndes, F. Micheli, C. O'Hara, C. Scarborough, and K. A. Selkoe. 2019. Recent pace of change in human impact on the world's ocean. *Scientific Reports* 9(1):1–8.

Halpern, B. S., M. Frazier, J. Potapenko, K. S. Casey, K. Koenig, C. Longo, J. S. Lowndes, R. C. Rockwood, E. R. Selig, K. A. Selkoe, and S. Walbridge. 2015. Spatial and temporal changes in cumulative human impacts on the world's ocean. *Nature Communications* 6:7615.

Hamann, M., K. Berry, T. Chaigneau, T. Curry, R. Heilmayr, P. J. G. Henriksson, J. Hentati-Sundberg, A. Jina, E. Lindkvist, Y. Lopez-Maldonado, E. Nieminen, M. Piaggio, J. Qiu, J. C. Rocha, C. Schill, A. Shepon, A. R. Tilman, I. Van Den Bijgaart, and T. Wu. 2018. Inequality and the Biosphere. *Annual Review of Environment and Resources*.

Helbing, D. 2013. Globally networked risks and how to respond. *Nature* 497:51–9.

Hilborn, R., R. O. Amoroso, C. M. Anderson, J. K. Baum, T. A. Branch, C. Costello, C. L. De Moor, A. Faraj, D. Hively, O. P. Jensen, H. Kurota, L. R. Little, P. Mace, T. McClanahan, M. C. Melnychuk, C. Minto, G. C. Osio, A. M. Parma, M. Pons, S. Segurado, C. S. Szuwalski, J. R. Wilson, and Y. Ye. 2020. Effective fisheries management instrumental in improving fish stock status. *Proceedings of the National Academy of Sciences of the United States of America* 117(4):2218–2224.

Hughes, T. P., S. Carpenter, J. Rockström, M. Scheffer, and B. Walker. 2013. Multiscale regime shifts and planetary boundaries. *Trends in Ecology & Evolution* 28(7):389–395.

Hughes, T. P., N. A. J. Graham, J. B. C. Jackson, P. J. Mumby, and R. S. Steneck. 2010. Rising to the challenge of sustaining coral reef resilience.

IFRC. 2020. *World Disasters Report 2020: Come Heat or High Water*. Page *World Disaster Report 2020*. Geneva.

IPBES. 2016. *The assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services on pollinators, pollination and food production. S. G. Potts, V. L. Imperatriz-Fonseca, and H. T. Ngo (eds).* Page (S. Potts, V. Imperatriz-Fonseca, and H. Ngo, editors). Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn.

IPBES. 2019. *Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. Page (E. S. Brondizio, J. Settele, S. Diaz, and H. Ngo, editors). IPBES Secretariat, Bonn, Germany.

IPCC. 2014. *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Page (R. Pachauri and L. Meyer, editors). Cambridge University Press, Geneva.

IPCC. 2019. *Summary for Policymakers. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems*. Page *International Encyclopedia of Geography: People, the Earth, Environment and Technology*.

IUCN. 2021. *DEFORESTATION AND FOREST DEGRADATION*. Page *IUCN issues briefs*.

Jonas, O. B. 2014. *World Development Report: Pandemic risk*.

Jones, K. E., N. G. Patel, M. A. Levy, A. Storeygard, D. Balk, J. L. Gittleman, and P. Daszak. 2008. Global trends in emerging infectious diseases. *Nature* 451(7181):990–993.

Jørgensen, P. S., A. Aktipis, Z. Brown, Y. Carrière, S. Downes, R. R. Dunn, G. Epstein, G. B. Frisvold, D. Hawthorne, Y. T. Gröhn, G. T. Gujar, D. Jasovský, E. Y. Klein, F. Klein, G. Lhermie, D. Mota-Sanchez, C. Omoto, M. Schlüter, H. M. Scott, D. Wernli, and S. P. Carroll. 2018. Antibiotic and pesticide susceptibility and the Anthropocene operating space. *Nature Sustainability* 1(11):632–641.

Jouffray, J., R. Blasiak, A. V. Norström, H. Österblom, and M. Nyström. 2020. The Blue Acceleration: The Trajectory of Human Expansion into the Ocean. *One Earth* 2(1):43–54.

Keys, P. W., V. Galaz, M. Dyer, N. Matthews, C. Folke, M. Nyström, and S. E. Cornell. 2019. Anthropocene risk. *Nature Sustainability* 2(August):667–673.

Klein, A.-M., B. E. Vaissière, J. H. Cane, I. Steffan-Dewenter, S. A. Cunningham, C. Kremen, and T. Tscharntke. 2007. Importance of pollinators in changing landscapes for world crops. *Proceedings of the Royal Society B: Biological Sciences* 274(1608):303–313.

Krampe, F. 2019. *Climate change, peacebuilding and sustaining peace*.

Laxminarayan, R., P. Matsoso, S. Pant, C. Brower, J. A. Røttingen, K. Klugman, and S. Davies. 2016. Access to effective antimicrobials: A worldwide challenge. *The Lancet* 387(10014):168–175.

Leach, M., B. Reyers, X. Bai, E. S. Brondizio, C. Cook, S. Díaz, G. Espindola, M. Scobie, M. Stafford-Smith, and S. M. Subramanian. 2018. Equity and sustainability in the Anthropocene: a social–ecological systems perspective on their intertwined futures. *Global Sustainability* 1:e13.

Lee, S., D. Schmidt-Klau, and S. Verick. 2020. The Labour Market Impacts of the COVID-19: A Global Perspective. *Indian Journal of Labour Economics* 63(s1):11–15.

Lenton, T. M., J. Rockström, O. Gaffney, S. Rahmstorf, K. Richardson, W. Steffen, and H. J. Schellnhuber. 2019. Climate tipping points—too risky to bet against. *Nature* 575(7784):592–595.

Levia, D. F., I. F. Creed, D. M. Hannah, K. Nanko, E. W. Boyer, D. E. Carlyle-Moses, N. van de Giesen, D. Grasso, A. J. Guswa, J. E. Hudson, S. A. Hudson, S. Iida, R. B. Jackson, G. G. Katul, T. Kumagai, P. Llorens, F. L. Ribeiro, D. E. Pataki, C. A. Peters, D. S. Carretero, J. S. Selker, D. Tetzlaff, M. Zalewski, and M. Bruen. 2020. Homogenization of the terrestrial water cycle. *Nature Geoscience* 13(10):656–658.

Mace, G. M., K. Norris, and A. H. Fitter. 2012. Biodiversity and ecosystem services: a multilayered relationship. *Trends in ecology & evolution* 27(1):19–26.

Mace, G. M., B. Reyers, R. Alkemade, R. Biggs, F. S. Chapin, S. E. Cornell, S. Díaz, S. Jennings, P. Leadley, P. J. Mumby, A. Purvis, R. J. Scholes, A. W. R. Seddon, M. Solan, W. Steffen, and G. Woodward. 2014. Approaches to defining a planetary boundary for biodiversity. *Global Environmental Change* 28:289–297.

Managi, S. 2018. *Inclusive Wealth Report 2018*. Page (S. Managi and P. Kumar, editors) *Inclusive Wealth Report 2018*. Routledge.

Marco, M. Di, M. L. Baker, P. Daszak, P. de Barro, E. A. Eskew, C. M. Godde, T. D. Harwood, M. Herrero, A. J. Hoskins, E. Johnson, W. B. Karesh, C. Machalaba, J. N. Garcia, D. Paini, R. Pirzl, M. S. Smith, C. Zambrana-Torrelio, and S. Ferrier. 2020. Sustainable development must account for pandemic risk. *Proceedings of the National Academy of Sciences of the United States of America* 117(8):3888–3892.

Mbaye, A. A. 2020. Climate Change, Livelihoods, and Conflict in the Sahel. *Georgetown Journal of International Affairs* 21(1):12–20.

Milkoreit, M., J. Hodbod, J. Baggio, K. Benessaiah, R. Calderón-Contreras, J. F. Donges, J. D. Mathias, J. C. Rocha, M. Schoon, and S. E. Werners. 2018. Defining tipping points for social-ecological systems scholarship - An interdisciplinary literature review. *Environmental Research Letters* 13(3).

Myers, S. S., and J. A. Patz. 2009. Emerging threats to human health from global environmental change. *Annual Review of Environment and Resources* 34:223–252.

Myers, S. S., M. R. Smith, S. Guth, C. D. Golden, B. Vaitla, N. D. Mueller, A. D. Dangour, and P. Huybers. 2017. Climate Change and Global Food Systems: Potential Impacts on Food Security and Undernutrition. *Annual Review of Public Health* 38(1):259–277.

Nagelkerken, I., and S. D. Connell. 2015. Global alteration of ocean ecosystem functioning due to increasing human CO 2 emissions. *Proceedings of the National Academy of Sciences*:201510856.

Nyström, M., J.-B. Jouffray, A. V. Norström, B. Crona, P. Søgaard Jørgensen, S. R. Carpenter, Ö. Bodin, V. Galaz, and C. Folke. 2019. Anatomy and resilience of the global production ecosystem. *Nature* 575(7781):98–108.

O'Neill, D. W., A. L. Fanning, W. F. Lamb, and J. K. Steinberger. 2018. A good life for all within planetary boundaries. *Nature Sustainability* 1(2):88–95.

Oliver, E. C. J., M. G. Donat, M. T. Burrows, P. J. Moore, D. A. Smale, L. V. Alexander, J. A. Benthuysen, M. Feng, A. Sen Gupta, A. J. Hobday, N. J. Holbrook, S. E. Perkins-Kirkpatrick, H. A. Scannell, S. C. Straub, and T. Wernberg. 2018. Longer and more frequent marine heatwaves over the past century. *Nature Communications* 9(1):1–12.

Österblom, H., J.-B. Jouffray, C. Folke, B. Crona, M. Troell, A. Merrie, and J. Rockström. 2015. Transnational Corporations as 'Keystone Actors' in Marine Ecosystems. *PLOS ONE* 10(5):e0127533.

Otto, I. M., J. F. Donges, R. Cremades, A. Bhowmik, R. J. Hewitt, W. Lucht, J. Rockström, F. Allerberger, M. McCaffrey, S. S. P. Doe, A. Lenferna, N. Morán, D. P. van Vuuren, and H. J. Schellnhuber. 2020. Social tipping dynamics for stabilizing Earth's climate by 2050. *Proceedings of the National Academy of Sciences*:201900577.

Pandolfi, J. M., S. R. Connolly, D. J. Marshall, and A. L. Cohen. 2011. Projecting coral reef futures under global warming and ocean acidification. *Science* 333(6041):418–422.

Pascual, U., W. M. Adams, S. Díaz, S. Lele, G. M. Mace, and E. Turnhout. 2021. Biodiversity and the challenge of pluralism. *Nature Sustainability*.

Pauly, D., J. Alder, E. Bennett, V. Christensen, P. Tyedmers, and R. D. A.-N. O. V. 21 Watson. 2003. The future for fisheries. *Science* 302(5649):1359-1361 ST-The future for fisheries.

Phillips, C. A., A. Caldas, R. Cleetus, K. A. Dahl, J. Declet-Barreto, R. Licker, L. D. Merner, J. P. Ortiz-Partida, A. L. Phelan, E. Spanger-Siegfried, S. Talati, C. H. Trisos, and C. J. Carlson. 2020. Compound climate risks in the COVID-19 pandemic. *Nature Climate Change*.

Pomeroy, R., J. Parks, R. Pollnac, T. Campson, E. Genio, C. Marlessy, E. Holle, M. Pido, A. Nissapa, S. Boromthanarat, and N. Thu Hue. 2007. Fish wars: Conflict and collaboration in fisheries management in Southeast Asia. *Marine Policy* 31(6):645–656.

Porkka, M., M. Kummu, S. Siebert, and O. Varis. 2013. From food insufficiency towards trade dependency: A historical analysis of global food availability. *PLOS ONE* 8(12).

Queiroz, C., R. Beilin, C. Folke, and R. Lindborg. 2014. Farmland abandonment: threat or opportunity for biodiversity conservation? A global review. *Frontiers in Ecology and the Environment* 12(5):288–296.

Quéré, C. Le, G. P. Peters, P. Friedlingstein, R. M. Andrew, J. G. Canadell, S. J. Davis, R. B. Jackson, and M. W. Jones. 2021. Fossil CO 2 emissions in the post-COVID-19 era. *Nature Climate Change* 11(March).

Raworth, K. 2017. A Doughnut for the Anthropocene: humanity's compass in the 21st century. *The Lancet Planetary Health* 1(2):e48–e49.

Reid, W. V., D. Chen, L. Goldfarb, H. Hackmann, Y. T. Lee, K. Mokhele, E. Ostrom, K. Raivio, J. Rockstrom, H. J. Schellnhuber, and A. Whyte. 2010. Earth system science for global sustainability: grand challenges. *Science* 330(6006):916–917.

Rist, L., A. Felton, M. Nyström, M. Troell, R. A. Sponseller, J. Bengtsson, H. Österblom, R. Lindborg, P. Tidåker, D. G. Angeler, R. Milestad, and J. Moen. 2014. Applying resilience thinking to production ecosystems. *Ecosphere* 5(6):art73.

Rocha, J. C., G. Peterson, Ö. Bodin, and S. Levin. 2018. Cascading regime shifts within and across scales. *Science* 362(6421):1379–1383.

Rocha, J., J. Yletyinen, R. Biggs, T. Blenckner, and G. Peterson. 2014. Marine regime shifts: drivers and impacts on ecosystems services. *Philosophical Transactions of the Royal Society B: Biological Sciences* 370(1659):20130273–20130273.

Rockström, J., M. Falkenmark, T. Allan, C. Folke, L. Gordon, A. Jägerskog, M. Kummu, M. Lannerstad, M. Meybeck, D. Molden, S. Postel, H. H. G. Savenije, U. Svedin, A. Turton, and O. Varis. 2014. The unfolding water drama in the Anthropocene: Towards a resilience-based perspective on water for global sustainability. *Ecohydrology* 7(5):1249–1261.

Rockström, J., W. Steffen, K. Noone, A. Persson, F. S. Chapin, E. F. Lambin, T. M. Lenton, M. Scheffer, C. Folke, H. J. Schellnhuber, B. Nykvist, C. A. de Wit, T. Hughes, S. van der Leeuw, H. Rodhe, S. Sörlin, P. K. Snyder, R. Costanza, U. Svedin, M. Falkenmark, L. Karlberg, R. W. Corell, V. J. Fabry, J. Hansen, B. Walker, D. Liverman, K. Richardson, P. Crutzen, and J. A. Foley. 2009. A safe operating space for humanity. *Nature* 461(7263):472–5.

Sánchez-Bayo, F., and K. A. G. Wyckhuys. 2019. Worldwide decline of the entomofauna:A review of its drivers. *Biological Conservation* 232(September 2018):8–27.

Scheffer, M., B. van Bavel, I. A. van de Leemput, and E. H. van Nes. 2017. Inequality in nature and society. *Proceedings of the National Academy of Sciences* 114(50):13154–13157.

Scheffer, M., S. Carpenter, J. A. Foley, C. Folke, and B. Walker. 2001. Catastrophic shifts in ecosystems. *Nature* 413(6856):591–6.

Seekell, D., J. Carr, J. Dell'Angelo, P. D'Odorico, M. Fader, J. Gephart, M. Kummu, N. Magliocca, M. Porkka, M. Puma, Z. Ratajczak, M. C. Rulli, S. Suweis, and A. Tavoni. 2017. Resilience in the global food system. *Environmental Research Letters* 12(2).

Smale, D. A., T. Wernberg, E. C. J. Oliver, M. Thomsen, B. P. Harvey, S. C. Straub, M. T. Burrows, L. V. Alexander, J. A. Benthuysen, M. G. Donat, M. Feng, A. J. Hobday, N. J. Holbrook, S. E. Perkins-Kirkpatrick, H. A. Scannell, A. Sen Gupta, B. L. Payne, and P. J. Moore. 2019. Marine heatwaves threaten global biodiversity and the provision of ecosystem services. *Nature Climate Change* 9(4):306–312.

Spera, S. A., J. M. Winter, and T. F. Partridge. 2020. Brazilian maize yields negatively affected by climate after land clearing. *Nature Sustainability* 3(10):845–852.

Spijkers, J., G. Singh, R. Blasiak, T. H. Morrison, P. Le Billon, and H. Österblom. 2019. Global patterns of fisheries conflict: Forty years of data. *Global Environmental Change* 57(May).

Spijkers, O. 2018. Intergenerational Equity and the Sustainable Development Goals. *Sustainability* 10(11):3836.

Steffen, W., W. Broadgate, L. Deutsch, O. Gaffney, and C. Ludwig. 2015a. The trajectory of the Anthropocene: The Great Acceleration. *The Anthropocene Review* 2(1):81–98.

Steffen, W., J. Crutzen, and J. R. McNeill. 2007. The Anthropocene: are humans now overwhelming the great forces of Nature? *Ambio* 36(8):614–621.

Steffen, W., Å. Persson, L. Deutsch, J. Zalasiewicz, M. Williams, K. Richardson, C. Crumley, P. Crutzen, C. Folke, L. Gordon, M. Molina, V. Ramanathan, J. Rockström, M. Scheffer, H. J. Schellnhuber, and U. Svedin. 2011. The Anthropocene: from global change to planetary stewardship. *AMBIO* 40:739–761.

Steffen, W., K. Richardson, J. Rockstrom, S. E. Cornell, I. Fetzer, E. M. Bennett, R. Biggs, S. R. Carpenter, W. de Vries, C. A. de Wit, C. Folke, D. Gerten, J. Heinke, G. M. Mace, L. M. Persson, V. Ramanathan, B. Reyers, and S. Sorlin. 2015b. Planetary boundaries: Guiding human development on a changing planet. *Science* 347(6223):1259855–1259855.

Steffen, W., J. Rockström, K. Richardson, T. M. Lenton, C. Folke, D. Liverman, C. P. Summerhayes, A. D. Barnosky, S. E. Cornell, M. Crucifix, J. F. Donges, I. Fetzer, S. J. Lade, M. Scheffer, R. Winkelmann, and H. J. Schellnhuber. 2018. Trajectories of the Earth system in the anthropocene. *Proceedings of the National Academy of Sciences* 115(33):8252–8259.

Stewart, F. 2016. Changing Perspectives on Inequality and Development. *Studies in Comparative International Development* 51(1):60–80.

Subramanian, M. 2019. Humans versus Earth: the quest to define the Anthropocene. *Nature* 572(7768):168–170.

Sumaila, U. R., W. W. L. Cheung, V. W. Y. Lam, D. Pauly, and S. Herrick. 2011, December 20. Climate change impacts on the biophysics and economics of world fisheries. Nature Publishing Group.

Thiault, L., C. Mora, J. E. Cinner, W. W. L. Cheung, N. A. J. Graham, F. A. Januchowski-Hartley, D. Mouillot, U. R. Sumaila, and J. Claudet. 2019. Escaping the perfect storm of simultaneous climate change impacts on agriculture and marine fisheries. *Science Advances* 5(11):eaaw9976.

Troell, M., R. L. Naylor, M. Metian, M. Beveridge, P. H. Tyedmers, C. Folke, K. J. Arrow, S. Barrett, A.-S. Crépin, P. R. Ehrlich, A. Gren, N. Kautsky, S. A. Levin, K. Nyborg, H. Österblom, S. Polasky, M. Scheffer, B. H. Walker, T. Xepapadeas, and A. de Zeeuw. 2014. Does aquaculture add resilience to the global food system? *Proceedings of the National Academy of Sciences of the United States of America* 111(37):13257–63.

Watts, N., W. N. Adger, S. Ayeb-Karlsson, Y. Bai, P. Byass, D. Campbell-Lendrum, T. Colbourn, P. Cox, M. Davies, M. Depledge, A. Depoux, P. Dominguez-Salas, P. Drummond, P. Ekins, A. Flahault, D. Grace, H. Graham, A. Haines, I. Hamilton, A. Johnson, I. Kelman, S. Kovats, L. Liang, M. Lott, R. Lowe, Y. Luo, G. Mace, M. Maslin, K. Morrissey, K. Murray, T. Neville, M. Nilsson, T. Oreszczyn, C. Parthemore, D. Pencheon, E. Robinson, S. Schütte, J. Shumake-Guillemot, P. Vineis, P. Wilkinson, N. Wheeler, B. Xu, J. Yang, Y. Yin, C. Yu, P. Gong, H. Montgomery, and A. Costello. 2017. The Lancet Countdown: tracking progress on health and climate change. *The Lancet* 389(10074):1151–1164.

Waycott, M., C. M. Duarte, T. J. B. Carruthers, R. J. Orth, W. C. Dennison, S. Olyarnik, A. Calladine, J. W. Fourqurean, K. L. Heck, A. R. Hughes, G. A. Kendrick, W. J. Kenworthy, F. T. Short, and S. L. Williams. 2009. Accelerating loss of seagrasses across the globe threatens coastal ecosystems. *Proceedings of the National Academy of Sciences of the United States of America* 106(30):12377–81.

Wilkinson, D. A., J. C. Marshall, N. P. French, and D. T. S. Hayman. 2018. Habitat fragmentation, biodiversity loss and the risk of novel infectious disease emergence. *Journal of the Royal Society Interface* 15(149).

Winkler, K., R. Fuchs, M. Rounsevell, and M. Herold. 2021. Global land use changes are four times greater than previously estimated. *Nature Communications* 12(1):1–10.

WMO. 2019. *United In Science: High-level synthesis report of latest climate science information convened by the Science Advisory Group of the UN Climate Action Summit 2019.*

WMO. 2020. Global Annual to Decadal Climate Update:1–16.

Worm, B., R. Hilborn, J. K. Baum, T. A. Branch, J. S. Collie, C. Costello, M. J. Fogarty, E. A. Fulton, J. A. Hutchings, S. Jennings, O. P. Jensen, H. K. Lotze, P. M. Mace, T. R. McClanahan, C. Minto, S. R. Palumbi, A. M. Parma, D. Ricard, A. A. Rosenberg, R. Watson, and D. D. A.-J. Zeller 2009 DO - 10.1126/science.1173146. 2009. Rebuilding Global Fisheries. *Science* 325(5940):578–585.

WWF. 2020. *Living Planet Report 2020 - Bending the curve of biodiversity loss*. Page *Wwf*.

Xu, C., T. A. Kohler, T. M. Lenton, J. C. Svenning, and M. Scheffer. 2020. Future of the human climate niche. *Proceedings of the National Academy of Sciences of the United States of America* 117(21).