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RESEARCH ARTICLE

Levers and leverage points for pathways to sustainability

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Abstract

1. Humanity is on a deeply unsustainable trajectory. We are exceeding planetary boundaries and unlikely to meet many international sustainable development goals and global environmental targets. Until recently, there was no broadly accepted

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framework of interventions that could ignite the transformations needed to achieve these desired targets and goals.
2. As a component of the IPBES Global Assessment, we conducted an iterative expert deliberation process with an extensive review of scenarios and pathways to sustainability, including the broader literature on indirect drivers, social change and sustainability transformation. We asked, what are the most important elements of pathways to sustainability?
3. Applying a social–ecological systems lens, we identified eight priority points for intervention (leverage points) and five overarching strategic actions and priority interventions (levers), which appear to be key to societal transformation. The eight *leverage points* are: (1) Visions of a good life, (2) Total consumption and waste, (3) Latent values of responsibility, (4) Inequalities, (5) Justice and inclusion in conservation, (6) Externalities from trade and other telecouplings, (7) Responsible technology, innovation and investment, and (8) Education and knowledge generation and sharing. The five intertwined *levers* can be applied across the eight leverage points and more broadly. These include: (A) Incentives and capacity building, (B) Coordination across sectors and jurisdictions, (C) Pre-emptive action, (D) Adaptive decision-making and (E) Environmental law and implementation. The levers and leverage points are all non-substitutable, and each enables others, likely leading to synergistic benefits.
4. Transformative change towards sustainable pathways requires more than a simple scaling-up of sustainability initiatives—it entails addressing these levers and leverage points to change the fabric of legal, political, economic and other social systems. These levers and leverage points build upon those approved within the Global Assessment's Summary for Policymakers, with the aim of enabling leaders in government, business, civil society and academia to spark transformative changes towards a more just and sustainable world.

KEYWORDS
biodiversity, ecosystem services, governance interventions, human population size, indirect drivers, Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), policy, relational values

1 | INTRODUCTION

It is now evident that achieving key societal goals associated with sustainability and the environment (Table 1) will require transformative change—'fundamental, system-wide reorganization across technological, economic and social factors, including paradigms, goals and values' (Butchart et al., 2019; Chan et al., 2019; IPBES, 2019b, p. 14; IPCC, 2018; Mace et al., 2018, Razzaque et al., 2019; Sachs et al., 2019). Without transformative change, humanity is at risk of losing up to a million species in the near term (Purvis et al., 2019), degrading many of nature's crucial contributions to people (Brauman et al., 2019; Shin et al., 2019), increasing the risk of future zoonoses (UNEP, 2016) and triggering catastrophic climate change (IPCC, 2018). The societal imperative could scarcely be greater.

It is also clear that interventions in pursuit of just a few goals risk having negative effects on others and missing opportunities to realize synergies and manage trade-offs (Palomo et al., 2019; Singh et al., 2018; Tallis et al., 2018). Examples abound: mitigating climate change via geoengineering could threaten other sustainability targets via unequal distribution of costs and international conflict (Gregory, Satterfield, & Hasell, 2016; Keith, 2000). Similarly, intensive food production poses risks to biodiversity (Beckmann et al., 2019), fuels nutrient run-off that can trigger marine hypoxic zones and associated fisheries losses (Donner & Kucharik, 2008) and demands so much water that hydrological cycles and freshwater ecosystems can be undermined (Davis et al., 2015). Given such interacting effects, how might interventions address a broader suite of sustainability goals?

TABLE 1 Intergovernmental goals and targets for nature and sustainability, especially pertinent to this analysis (CBD, 2010b; IPCC, 2018; Sachs et al., 2019; United Nations, 2015). Throughout the text, we use 'sustainability' to mean a world consistent with these goals and targets (e.g. as in the CBD's 2050 vision for biodiversity)

Goal/target	Source	Time goal
Aichi targets and post-2020 biodiversity framework	Convention on Biological Diversity (CBD)	2020/2030
Sustainable development goals (SDGs)	United Nations	2020–2030
Limit temperature change to 'well below' 2°C and ideally <1.5°C	Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC)	By 2100

To address these complex social–ecological problems, our focus must expand beyond the *direct drivers* of change (i.e. processes directly affecting nature, land/sea-use change, direct exploitation, climate change, pollution, invasive species, etc., Brondízio et al., 2019; Díaz et al., 2015). In particular, our focus must include *indirect drivers* (including formal and informal institutions, such as norms, values, rules and governance systems, demographic and sociocultural factors, and economic and technological factors, Brondízio et al., 2019; Cumming et al., 2020; Díaz et al., 2015), which structure economic activities and propel direct drivers. It is well known—for instance—that a safe climate and a healthy biosphere require profound changes to direct drivers, such as phasing out fossil fuels or halting deforestation. However, direct drivers resist intervention because they underpin our current economies and governance institutions (Ehrlich & Pringle, 2008). Thus, interventions often spark considerable opposition from vested interests who benefit from the status quo, including its prevalent externalization of costs. Conversely, indirect drivers have yet to receive comprehensive directed attention in the context of their impacts on nature and its contributions to people, despite recognition of their importance in some literature oriented towards sustainability transitions or transformations (Broman & Robèrt, 2017; Geels, 2011; Griffiths, 2009; Rotmans, Kemp, & van Asselt, 2001; Shove & Walker, 2007; Westley et al., 2011). Given that the fate of nature and humanity depends on transformative change of the human enterprise (IPBES, 2019a, 2019b), indirect drivers clearly play a central role.

Two linked concepts are relevant to prioritizing indirect drivers: *leverage points* (where to intervene to change social–ecological systems) and *levers* (the means of realizing these changes, such as governance approaches and interventions). Both concepts are intended to identify which changes, for which social variables, are likely to have disproportionately large positive effects on social–ecological systems (Meadows, 2009). Although these and related concepts have received attention in sustainability circles (Abson et al., 2017; Fischer & Riechers, 2019), thus far they have been applied only to specific contexts (Scullion et al., 2016) or specific combinations of global goals (West et al., 2014). Related concepts include positive tipping points, sensitive intervention points and social tipping interventions (Farmer et al., 2019; Otto et al., 2020; Tàbara et al., 2018). Levers and leverage points for a broad suite of sustainability objectives might share much in common with those identified for climate and other contexts, but they are also likely to differ.

Many intergovernmental calls for transformative change seem to suggest it can be accomplished by simply scaling-up existing sustainability initiatives (UN Environment, 2019b). The IPBES Global Assessment represented a stark departure from that position, identifying what might be considered a set of elements for sustainable futures—levers and leverage points (Chan et al. 2019; IPBES, 2019b). In this paper, we build upon that effort by detailing the methodology for identifying these levers and leverage points, and their basis and tensions in the academic literature and in practice. Clearly, policy action to address emerging threats is not a straightforward function of the quality of the evidence (Michaels, 2008; Oreskes, 2004). Thus, a key consideration is how this knowledge resonates with decision makers, and its feasibility for application (Cash et al., 2003).

This paper draws upon and builds upon Chapter 5 (pathways towards a sustainable future) of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) Global Assessment to address three primary research questions. (a) What are the key levers and leverage points in social systems that might drive transformative change towards sustainability? (b) How are these derived from and perceived within and across academic literatures and in practice? (c) How might the levers and leverage points work together? Our intended audience includes diverse scholars and agents of change in civil society, government, business and elsewhere. In particular, these levers and leverage points emerged from consideration of six linked focal issues, including producing food, protecting biodiversity (both on land and in the water), maintaining freshwater supplies and mitigating climate change, all while providing for our growing cities (Aguiar et al., in review; Chan et al., 2019). It thus draws upon a comprehensive 'nexus' analysis (Liu et al., 2018) of scenarios and pathways (Aguiar et al., in review), as well as literature reviews on various indirect drivers and dimensions of social and institutional change (Chan et al., 2019). We conclude by discussing current gaps and ways forward, including obstacles and opportunities for transformative changes.

2 | METHODS

Levers and leverage points were identified using an iterative expert deliberation process (inspired by Burgman et al., 2011; Singh et al., 2019; Wiklund, 2005), tailored for this purpose and supplemented with review of published literature, peer review and four meetings (Figure 1). First, we relied on chosen experts to identify a preliminary set of levers and leverage points based on their expertise. A total of 22 experts from 14 nations were nominated and selected according to IPBES procedures including criteria ensuring diversity

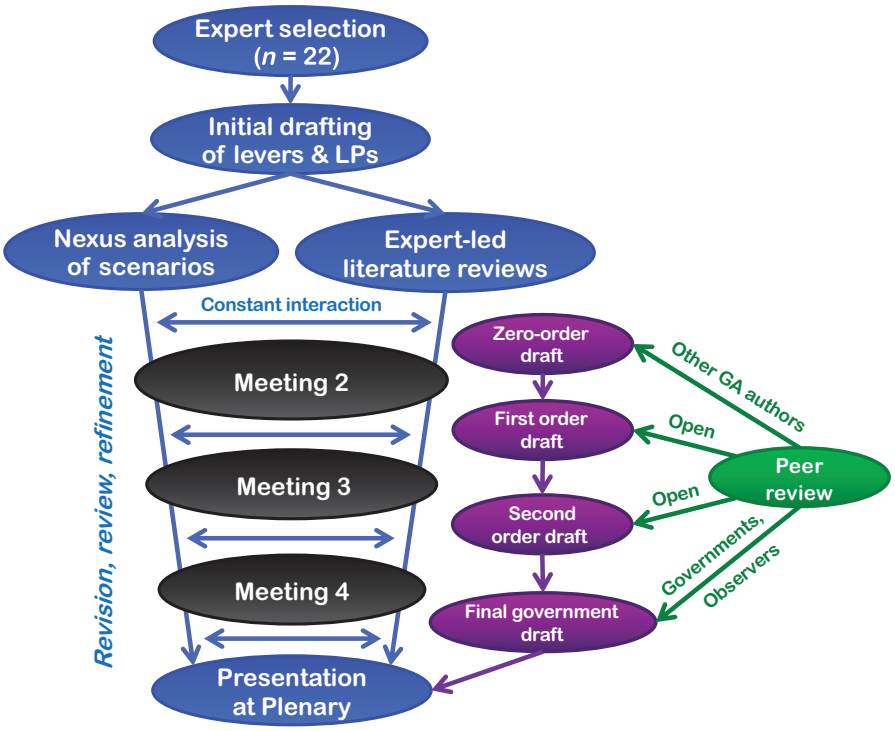

FIGURE 1 Workflow for identification of levers and leverage points (LPs). Two major processes (blue; nexus analysis of scenarios and expert-led literature reviews, both including additional contributing authors) included many points of interaction and internal review, especially at meetings/workshops (black). Outputs (purple) were subject to peer review (green). The levers and LPs were drafted in a very preliminary way at the First Authors Meeting in August 2016; subsequent meetings in February 2017, September 2017 and July 2018 were key moments for revision, reviewing and refining these. The IPBES-7 Plenary took place in Paris in April–May 2019

across regions and gender identity, to serve as authors for Chapter 5 (pathways towards a sustainable future) of the IPBES Global Assessment. In addition to their publication records, these authors brought together diverse experiences with environmental management, conservation and social–ecological systems. The experts were asked to independently provide a comprehensive list of levers and leverage points for global sustainability, based on the potential for disproportionate effects to address and reverse the deterioration of nature while meeting societal needs. They were asked to consider actions by the full range of possible actors, and both top-down and bottom-up effects across various sectors. The collection of all responses became our initial set of levers and leverage points. Ensuing processes were then informed by five linked conceptualizations of transformative change identified by the experts (Chan et al., 2019):

- Complexity theory and leverage points of transformation (Levin et al., 2013; Liu et al., 2007; Meadows, 2009);
- Resilience, adaptability and transformability in social–ecological systems (Berkes, Colding, & Folke, 2003; Folke et al., 2010);
- A multi-level perspective for transformative change (Geels, 2002);
- System innovations and their dynamics (Smits, Kuhlmann, & Teubal, 2010; OECD, 2015) and
- Learning sustainability through 'real-world experiments' (Geels, Berkhout, & van Vuuren, 2016; Gross & Krohn, 2005; Hajer, 2011).

After determining the initial set of levers and leverage points, two parallel but interactive processes contributed to their refinement. One was a nexus analysis (Liu et al., 2018) of intervention scenarios (Ferrier et al., 2016) at multiple scales to derive information about pathways, an analysis which was based on systematic literature reviews as described in Chan et al. (2019) and Aguiar et al. (in review). The second process focused on the levers (e.g. incentives) and leverage points (e.g. consumption), and was based on expert-led literature reviews on factors affecting social and institutional change in the context of sustainability.

2.1 | Nexus analysis of scenarios and pathways

While the nexus analysis was designed to offer insights about concrete actions in support of particular sets of goals, it also contributed to identifying those levers and leverage points that are key to achieving transformative changes leading to more sustainable pathways of development (see iterative process, below). Accordingly, we present these methods briefly. To reflect the global transformative change required, our analysis considered how to depart from existing development pathways, vested interests and entrenched structures, to make space for new and more sustainable pathways (Leach, Scoones, & Stirling, 2010; Loorbach, Frantzeskaki, & Avelino, 2017; Sharpe, Hodgson, Leicester, Lyon, & Fazey, 2016). While such transformative change may involve novel processes, it can also involve deepening and accelerating existing processes of change.

In particular, pathways examined here addressed a nexus with **six foci** of analysis, which were chosen to represent important nature-related challenges to sustainable development and to reflect the underlying bodies of literature (e.g. food production is split between the land and the oceans). These six were considered separately while attending to interdependencies:

- Feeding humanity without deteriorating nature on land;
- Meeting climate goals while maintaining nature and nature's contributions to people;

- Conserving and restoring nature on land while contributing positively to human well-being;
- Maintaining freshwater for nature and humanity;
- Balancing food provision from oceans and coasts with nature protection; and
- Resourcing growing cities while maintaining the nature that underpins them.

For each focus, we conducted systematic literature reviews to identify relevant optimistic scenarios and pathway analyses (Chan et al., 2019). We compiled these studies into a database and analysed each with respect to its spatial and temporal scope and scale, goal or vision, scenario type, sectors and pathway elements (including measures, policies and other changes). The six foci are similar to the clusters of Global Environment Outlook 6 (UN Environment, 2019b), which orient around the SDGs, with differences to more strongly integrate biodiversity. These foci are the primary inputs to the cross-cutting insights in the Results.

2.2 | Expert-led literature reviews on factors affecting change

The reviews of factors affecting social and institutional change towards sustainability—that is, the identification of levers and leverage points—complemented the nexus analysis of scenarios and pathways (above). When the nexus analysis suggested that a given concept was important to the sustainability outcomes of pathways (e.g. consumption as a driver of environmental impact), the literature reviews sought to elaborate on those concepts and their underlying causes. Our approach was intentionally varied in order to appropriately represent the diversity of levers and leverage points (Meadows, 2009) and the diversity of scholarship underpinning each. We decided, for example, that a quantitative systematic review methodology in this section could bias findings towards particular perspectives and away from others (e.g. qualitative social sciences and humanities). Accordingly, we used a flexible approach. In each case, and each iteration, multiple authors from different perspectives contributed insights regarding how levers could affect the identified sustainable pathways. The experts wrote reviews of the levers and leverage points, backed by relevant literature, through an iterative peer review process. The reviews focused on how levers acting on leverage points contribute to sustainability goals, and sought to fill gaps in understanding that persisted after the initial set of levers and leverage points were determined.

2.3 | Iterative process of revision and review

Three rounds of peer review refined the levers and leverage points (Figure 1). Each round had both an internal and an external component (within the author team and open call respectively). Between these two components, at each round, three to eight authors and a collection of >5 external reviewers with expertise in the relevant lever and leverage points outlined areas of agreement or disagreement, and identified other relevant literature and findings. External reviewers were drawn via an open call from external academic researchers and representatives of organizations accredited with IPBES, and—especially in the third round—from government officials. The external review process was coordinated by IPBES' Technical Support Unit of the Global Assessment and overseen by an independent review editor. Each round of peer review yielded hundreds of comments that provided opportunity for revision and refinement.

Between each round of peer review, the expert authors met to revise and refine the list of levers and leverage points via a combination of workshops and email discussions (Figure 1). The intent was to minimize common expert biases such as dominance, overconfidence, framing effects and linguistic uncertainty (McBride et al., 2012). Clearly, limitations remain, and such processes are constrained by the underlying knowledge being assessed (Martin et al., 2012). Workshops were attended by the core author team (the aforementioned 22 experts); electronic discussions also included 12 additional 'contributing' authors who helped write text for one or more lever/leverage point section. Three coordinating lead authors (K. Chan, J. Agard, J. Liu) all worked to ensure a balanced representation of diverse views, with the assistance of three Co-Chairs (E. Brondizio, S. Díaz, J. Settele) and our review editor (K. Esler).

Because we are interested in global sustainability challenges, we sought levers and leverage points that were independently important, both regionally and globally. Towards this end, we refined levers and leverage points by lumping, splitting and adding key levers and leverage points. When the scenario analysis or the literature suggested that points were substitutable, or that they were parts of a broader meta-concept where some components were more relevant in some contexts, we lumped (e.g. population, per capita consumption and waste were integrated together in the leverage point 2, reduce total material consumption and waste). When a single point comprised several components that appeared to be implementable separately but independently important, we split [e.g. the concept of ecosystem-based management was split into three levers (B–D): Coordination across sectors and jurisdictions, Pre-emptive action and Adaptive decision-making]. When regional scenarios or the literature revealed that a point was likely inappropriate or irrelevant as phrased in some contexts, we amended that point. For instance, whereas some scenarios and literature pointed towards co-governance as a model for effective conservation under some circumstances, the available evidence did not support its necessity and effectiveness in all contexts. We thus broadened the phrasing so that the leverage point was broadly applicable, as in 'Practice justice and inclusion in conservation' [leverage point 5].

In this paper, we present text that differs slightly from that accepted as part of the Global Assessment in May 2019 (including the approval of the levers and leverage points in the Summary for Policymakers). This refined text better distinguishes leverage points from the changes that are conducive to sustainable pathways, and better reflects the latest evidence from the scenarios analysis and broader literature (e.g. a broadened scope for leverage point 5).

3 | RESULTS

3.1 | Cross-cutting insights

We synthesized the following six **cross-cutting insights** from the nexus analysis, which were used to structure the levers and leverage points (for more detail on scenarios and pathways, see Aguiar et al., in review; Chan et al., 2019; the latter also expands on all levers, leverage points and case studies/boxes).

No single strategy is likely to yield sufficient transformation to sustainable development and achieve the full suite of international goals for sustainability and nature. Rather, strategies entail large-scale change to society and its institutions, with both trade-offs and synergies. Identified pathways involved substantial expansion of protected areas and ecological restoration while integrating biodiversity considerations and safeguards in resource industries and rapidly moving away from fossil fuels, but they also entailed structural economic and legal changes to enable these steps. All foci suggested that pathways realizing multiple targets entailed various measures and instruments applied in concert at local, national, regional and global scales. All six foci involved trade-offs between sectors and social groups, such that compromises are inevitable as conflicting objectives are reconciled. However, the six foci also identified potential synergies where some actions offer benefits across multiple objectives and for many groups.

Consumption patterns are a fundamental driver of material extraction, production and flows, but they are in turn driven by worldviews and notions of good quality of life. Addressing aggregate consumption is a central constituent of pathways for all foci, and is especially useful for addressing trade-offs across foci (e.g. climate mitigation measures might rely more strongly on reducing energy demand than land-based carbon sequestration, to lessen conflicts with food production). The drivers of aggregate consumption were often implicit, for example, although many studies mentioned preferences, value systems and (less often) collective notions of a good quality of life as drivers of consumption, these aspects were generally not represented explicitly in scenarios and pathways.

Collective and organizational action—including behaviour change—pervade representations of transformative change, including supply chains, conservation and restoration. Consumption changes are intimately tied to habits and behavioural norms, but so too are changes in production practices (e.g. agroecological practices in farming), conservation and restoration. All six foci identified such behavioural and organizational change as central, but scenarios and pathways varied greatly in the detail with which they enabled this change. Many studies appealed to a combination of incentives and awareness raising, even though the latter is generally regarded to have only a weak influence on behaviour (Jacquet & Pauly, 2007; Schultz, 2011), an influence much less than infrastructure and regulations.

Equality and inclusiveness are key constituents of sustainable pathways and were addressed partly via participatory planning, but power disparities remain a challenge. Across the six foci, many studies highlighted the crucial importance of addressing inequalities and involving people in participatory planning, including the urban poor and Indigenous Peoples and local communities (IPLCs). But only a few scenarios and pathways addressed the barriers to transformative change that arise from substantial inequities in power, for example, in the food system, where studies highlighted the difficulties posed by corporate control of seeds, land, agricultural inputs and food distribution. Although the same issues are important in other foci—for example, industrial fishers and seafood distributors exert strong corporate control—they were generally not discussed explicitly in the studies we found.

Telecouplings, technology, innovation, investment, education and knowledge transmission underpin all of the above factors and mediate pathways to transformative change. Key elements of these structural considerations were often largely implicit in scenarios and pathways, despite their fundamental importance. The potential for interventions and actions to result in effects that are distant in space and/or time (via telecouplings) were often explicitly addressed in relation to cities, but were not explicitly addressed in other foci, despite clear representation of the processes that yield telecouplings (e.g. spatially disjunct supply and demand). Many studies across several foci discussed the potential gains from beneficial technologies (e.g. for climate mitigation), but few directly addressed the spread of technologies with harmful effects, or the importance of innovation and regulatory systems to make benign technology the norm. Education and knowledge transmission were often addressed in scenarios and pathways directly in the form of awareness raising for particular behavioural changes or technology transfer, but this leaves two crucial roles of knowledge systems implicit: ensuring well-functioning participatory processes (including political ones) and enabling the transmission of Indigenous and local knowledge for maintaining local capacities for stewardship.

Governance instruments and approaches such as incentives, adaptive management and law and its enforcement are widely recognized as fundamental components of sustainable pathways. There was near universal acknowledgement in the scenarios and pathways of the importance of several governance instruments and approaches, but more attention was paid to some aspects than others. For example, many studies across all foci appealed to the importance of economic incentives, but generally from a behaviourist perspective that treats behaviour as an individual decision. This approach lacks explicit recognition of how incentive programmes also effect change by articulating values at a societal level (see leverage point 3 and lever A below). Studies commonly discussed management and governance approaches as managing several sectors together (integrated management), but much less frequently discussed early action to address emerging threats (precaution) or managing for resilience and adaptation (these considerations were most explicit in the freshwater realm). Many studies across all foci identified particular environmental regulations, but fewer considered the role of consistent monitoring and enforcement and the broader rule

of law, although this is often crucial and implicit in scenarios and pathways.

These six insights led us to eight leverage points and five levers that are broadly important and apparently each necessary for transformations to sustainable futures. Thus, a ranking of importance is not possible nor necessary. Although each leverage point provides an opportunity for change towards or away from sustainable pathways, we focus below on changes that are conducive to sustainability. Our five levers are general and systemic interventions used in policy or governance to simultaneously address multiple leverage points and social variables (Figure 2). There are also important interactions between levers and leverage points, considered in the Section 4. Following the logic that there are no governance panaceas for social–ecological sustainability (Ostrom, 2007), implementation would surely vary considerably across contexts.

3.2 | Leverage points for transformative change

3.2.1 | Leverage point 1. Visions of a good life

Embracing visions of a good life that go beyond those entailing high levels of material consumption is central to many pathways. Key drivers of the overexploitation of nature are the currently popular vision that a good life involves happiness generated through material consumption [leverage point 2] and the widely accepted notion that economic growth is the most important goal of society, with success based largely on income and demonstrated purchasing power (Brand & Wissen, 2012). However, as communities around the world show, a good quality of life can be achieved with significantly lower environmental impacts than is normal for many affluent social strata (Jackson, 2011; Røpke, 1999). Alternative relational conceptions of a good life with a lower material impact (i.e. those focusing on the quality and characteristics of human relationships, and harmonious relationships with non-human nature) might be promoted and sustained by political settings that provide the *personal, material and social (interpersonal) conditions* for a good life (such as infrastructure, access to health or anti-discrimination policies), while leaving to individuals the choice about their actual way of living (Jackson, 2011; Nussbaum, 2001, 2003). In particular, status or social recognition need not require high levels of consumption, even though in some societies, status is currently related to consumption (Røpke, 1999).

In this respect, relational notions of a good quality of life, such as 'buen vivir' from Latin America (D'Alisa, Demaria, & Kallis, 2014; Gudynas, 2011; Hopkins, 2008), may be key to achieving long-term sustainable outcomes (Kohler et al., 2018). Evidence from around the world identifying circumstances that support high life satisfaction invariably shows that a number of socially mediated, non-material factors are primary in producing a good life (e.g. trust in neighbours, access to care, opportunities for creative expression, recognition; Barrington-Leigh & Galbraith, 2019; Nierling, 2012; Nussbaum, 2003). Education, infrastructure and policymaking that enable these factors may offer a path to sustainable development in which, beyond a certain threshold of income (Max-Neef, 1995), a good life can be sustained even if material constraints might tighten (Barrington-Leigh, 2016). By highlighting the contributions of relations with human and non-human others to a good life, we might not only contribute to decoupling consumption and well-being but

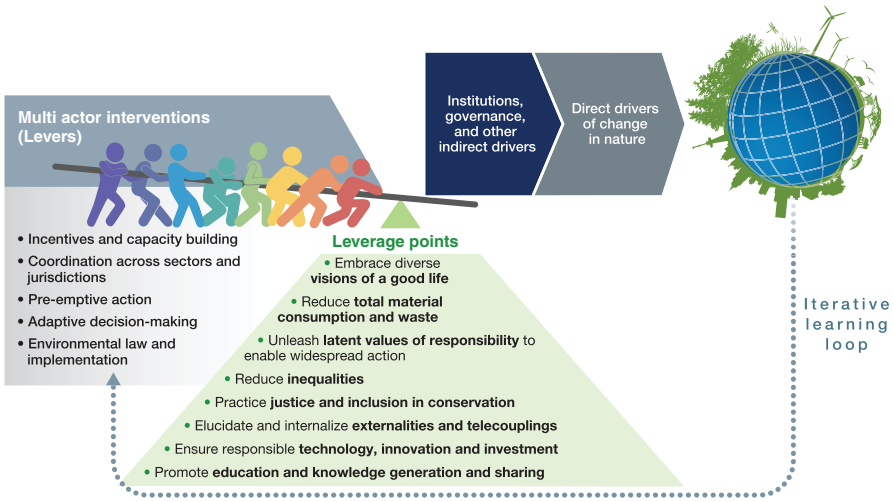

FIGURE 2 Collaborative implementation of priority interventions (levers) targeting key points of intervention (leverage points) could enable transformative change from current trends towards more sustainable ones. Most levers can be applied at multiple leverage points and more generally by a range of actors (such as intergovernmental organizations, governments, non-governmental organizations, citizen and community groups, IPLCs, donor agencies, science and educational organizations and the private sector), depending on context. At the leverage points (bolded), we have specified actions consistent with transformative change to sustainability (unbolded). This figure is adapted from IPBES (2019b), focusing on levers and leverage points, with slight wording modifications for consistency with the text; artist: Yuka Estrada

also enhance life experience (Chan et al., 2016; Jax et al., 2018; Muraca, 2016).

> An oft-touted implication is that conventional economics is unsuitable as a sole source of guidance for improving people's lives or measuring those improvements (e.g. GDP; Stiglitz, Fitoussi, & Durand, 2018). This 'visions of a good life' leverage point reflects the novel integration of insights from qualitative and quantitative research on subjective well-being. This interdisciplinary analysis suggests that addressing this leverage point will require grappling with the problem of choosing pathways amidst sometimes conflicting values and worldviews, which may require robust deliberative methods, and that disparities in power pose important challenges in this respect.

3.2.2 | Leverage point 2. Total material consumption and waste

Beyond improved efficiencies and enhanced production, all pathways intended to achieve biodiversity targets entail reducing or reversing the growth of aggregate material production, as a function of population size and per capita consumption and waste (Aguiar et al., in review). Per capita material consumption has risen alongside income, putting further pressure on nature (Dietz, Rosa, & York, 2007; Ehrlich & Holdren, 1971; Ehrlich & Pringle, 2008; Rosa, Dietz, & York, 2004). Since 1970, human population has doubled while total resource extraction rates have more than tripled (Balvanera et al., 2019; IRP, 2019). Upward trends in human population growth coupled with decreased household size and increased economic wealth have led and are likely to lead to further deterioration of nature, including increasing numbers of threatened species (Balvanera et al. 2019; IPBES, 2019a, 2019b; Liu, Daily, Ehrlich, & Luck, 2003; Pereira et al., 2010). Waste remains a crucial draw on resources, as a function of actors throughout supply chains (Parfitt, Barthel, & Macnaughton, 2010). Despite these various forces pushing the demand for resources ever higher, there are signs that we are reaching the limits of the planet's ability to yield those resources (Seppelt, Manceur, Liu, Fenichel, & Klotz, 2014). In light of inequalities within and between countries in consumption related to food, energy, water and other natural resources (O'Brien & Leichenko, 2009), the need for transformative changes in consumption patterns is particularly pertinent for wealthier nations and the rising global middle-class, given higher per capita levels of material consumption and aspirational effects on others. In contrast, for the most disadvantaged people in the world, material consumption must increase to meet multiple SDGs including eradicating poverty and hunger (McMichael et al., 2007); this may also help reduce unsustainably high rates of population growth in many regions if coupled with education and empowerment of women (Schultz, 1994).

> In contrast to the unhelpful but common argument about whether 'the problem' is population growth or consumption, it is not novel to argue that the problem is both—plus waste. Because of ongoing need for progress on all three, this point of intervention is nonetheless key. Unlike research on impact as a function of population, affluence and technology (1 = PAT), we point to strong opportunities to decouple affluence from material consumption [leverage point 1]. We also side with those who argue that more efficient production is insufficient, and that volumes of production and consumption are key variables (Bengtsson, Alfredsson, Cohen, Lorek, & Schroeder, 2018).

3.2.3 | Leverage point 3. Latent values of responsibility

Sustainable trajectories are often enabled by context-specific policies and social initiatives that foster and facilitate social norms conducive to sustainable behaviours; all scenarios and pathways reviewed entailed changes in human behaviour or action (Aguiar et al., in review). An important step towards such widespread changes in action would be to unleash latent capabilities and relational values (including virtues and principles regarding human relationships involving nature, such as responsibility, stewardship and care; Chan et al., 2016; Chan, Gould, & Pascual, 2018). In many cases, this may involve intentional broadening of existing norms (Raymond, Weldon, Kelly, Arriaga, & Clark, 2014) or co-evolution of values with changes in practice (Loorbach, 2010). For instance, a relational value of responsibility to do no harm to others may extend in its application from a mainly interpersonal context to also include environmental impacts from purchases expressed through supply chains, which impacts also affect people (Chan, Anderson, Chapman, Jespersen, & Olmsted, 2017). Promoting action may often include intervening at multiple levels to remove barriers, align incentives, impose constraints or otherwise facilitate action (Geels, 2011; Kemp, Loorbach, & Rotmans, 2007) [e.g. employing levers A and E]. Relational values of concern and responsibility are strongly held in several if not many populations (Klain, Olmsted, Chan, & Satterfield, 2017). Thus, the lack of large-scale environmental action is likely not due to a lack of concern but because conditions impede the expression of that concern, for example, via inappropriate or missing infrastructure and institutions, or powerful opposing forces with vested interests in the status quo (Chan, Olmsted, et al., 2017; Maller & Strengers, 2014; Shove & Walker, 2010). Barriers to enacting values held by communities are diverse and multifaceted (Pascual, Balvanera, et al., 2017); thus, social norm shifts and widespread action are most likely to stem from programmes, policies and investments that are tailored for sociocultural context.

Thus, relational values are a leverage point not because they are easily changed nor because they must change. Sometimes

these values can change (Britto dos Santos & Gould, 2018), but that is not necessarily required. Existing values may be sufficient to steer transformative change towards sustainability (e.g. Gould, Pai, Muraca, & Chan, 2019), if infrastructure and institutions change to manifest or facilitate the application of these already-held values. Whereas marginal change in behaviour might be accomplished without considering values, transformative change calls for employing relational values conducive to sustainability.

> This leverage point was identified by reviewers as an innovative leverage point given its focus on latent or dormant relational values of responsibility. In contrast, value change is commonly called for as key to sustainability, which frustrates a wide variety of social scientists who point out that value change seems to more often accompany widespread changes in human action than trigger it.

3.2.4 | Leverage point 4. Inequalities

Reducing inequalities is central to many sustainable pathways. Inequality often reflects excessive control and/or use of resources or power by one or more sectors of society at the expense of others. As societies develop and aim to 'catch up' in economic growth, inequality often emerges through control and distribution of unequal shares of finite resources and appropriation of 'inexpensive' labour through reduction in resource access. This distribution and appropriation contribute to unjust social conditions, environmental degradation and environmental injustices (Cáceres, 2015; Stiglitz, 2012). Although assessments of inequality often focus on income, there are many dimensions of societal inequalities such as distributive, recognition, procedural and contextual inequities (Leach, Reyers, & Bai, 2018). These inequalities cross many social differences, including gender, where inequality is an important driver of population growth and natural resource management (Ehrlich, Kareiva, & Daily, 2012). Therefore, addressing societal inequities—especially crippling poverty—is not only important for its own sake for moral reasons but also for its role in facilitating the protection of nature and achieving sustainable development (Knight & Rosa, 2011). In particular, poverty traps can fuel unsustainable resource exploitation, but they might be addressed via investments in health, governance and resource management; provision of alternatives to local resource extraction; reduced subsidies and capital investment; and enhanced equity in power and the distribution of resources (Bonds, Keenan, Rohani, & Sachs, 2010; McClanahan, Allison, & Cinner, 2015)—that is, all levers [A–E].

> Inequalities are commonly included as a key target of efforts towards sustainability, but usually as ends in themselves (as social sustainability; e.g. Rogers et al., 2012), rather than as a means to the end of environmental sustainability—our focus here. We found much less robust empirical research than we expected detailing how overcoming inequalities might enable environmental sustainability. The diverse studies cited above do constitute an interesting argument, although important uncertainties about the importance and the generality of the effect remain (Baland, Bardhan, & Bowles, 2018).

3.2.5 | Leverage point 5. Justice and inclusion in conservation

Just and inclusive approaches to conservation and restoration will be needed to attain sustainable pathways. Sustainable trajectories that achieve biodiversity targets and sustainable development goals entail a major escalation of conservation and restoration efforts (Díaz et al., 2019; Mace et al., 2018; Zabel et al., 2019). A diverse constituency, combined with intentional effort to create inclusive conservation initiatives and spaces, are crucial to this effort (Gould, Phukan, Mendoza, Ardoin, & Panikkar, 2018). Globally, a prime focus to increase inclusivity is to achieve large-scale engagement of IPLCs in governance and management of protected areas and other area-based conservation measures; successful efforts would maintain or enhance health and livelihood outcomes (Naidoo et al., 2019), including via local ecosystem services, which are particularly important to many IPLCs (Bawa & Gadgil, 1997). This large-scale engagement will require the following: (a) recognition of, and compensation for, historical wrongs and transgressions of rights in conservation contexts (Bennett et al., 2017; Chan & Satterfield, 2013); (b) IPLC-led planning, decision-making and consent (which are significant and robust; Garnett et al., 2018); (c) linking of local efforts with larger connected landscapes/seascapes to enable sustainable use of biodiversity and ecosystem services at local and broader scales (Ban et al., 2013) and (d) appropriate negotiation regarding the terms of conservation when objectives of IPLCs and of conservation do not fully align (Chan et al., 2007), following principles of Free, Prior and Informed Consent (as recognized under the United Nations Declaration on the Rights of Indigenous Peoples, UNDRIP). In many contexts, these steps would be facilitated by respecting, protecting and fulfilling human rights, making changes in law and policy and applying these instruments more consistently [lever E].

> It is certainly not new to bring attention to historical injustices associated with biological conservation (Brockington, Duffy, & Igoe, 2008; Chapin, 2004; Dowie, 2011; Neumann, 1998), but these issues continue to manifest in new ways (Bennett, Govan, & Satterfield, 2015) and proactively addressing them will be especially key as conservation efforts

necessarily address more populated landscapes (Sayer et al., 2013).

3.2.6 | Leverage point 6. Externalities and telecouplings

Achieving global sustainability goals will require a targeted focus to elucidate and internalize the distant effects of local actions (i.e. telecouplings), such as housing booms triggering distant deforestation via demand for wood products (Liu et al., 2013, 2015; Marques et al., 2019). Many existing environmental policy frameworks enable jurisdictions to meet targets by externalizing impacts to other jurisdictions (e.g. national greenhouse gas emissions and water use can and have been reduced in part by importing GHG- and water-intensive agricultural commodities rather than producing them; Pascual, Palomo, et al., 2017). While these actions may have benefits, global sustainability will require individuals, organizations and jurisdictions taking responsibility for distant, diffuse and delayed effects, including by assessing, avoiding and mitigating negative impacts (Aguiar et al., in review). Many environmental and social challenges faced in developing and least developed countries are consequences of meeting demands of the developed world. In theory, then, these challenges can be mitigated by responsible consumption practices in developed countries that enable improved production in developing countries [an example of lever B]. Improved traceability and transparency in supply chains and requirements for corporate due diligence are important steps [lever E] but would need enhanced transparency of environmental impacts and new measures for intervention in order to facilitate internalizing the many spillover effects of trade.

> While acknowledgement of the importance of externalities and telecouplings is central to whole fields such as environmental and ecological economics, the systemic elucidation and internalization called for here go well beyond what is generally cited as necessary action (Secretariat of the Convention on Biological Diversity, 2014; UN Environment, 2019a, 2019b). This leverage point has taken on newfound importance with the COVID-19 pandemic, which highlights that consumers' demand for some products results in harm to distant ecosystems, thus raising the risk of zoonotic emerging infectious diseases that can have global impacts (Johnson et al., 2020; Jones et al., 2008).

3.2.7 | Leverage point 7. Technology, innovation and investment

Pathways to a desirable societal future entail a regime change towards affordable technologies that reduce negative environmental impacts and towards those with net-positive impacts (Aguiar et al., in review). This leverage point thus addresses technological and social innovations that are proactive (not only reactive) and that go well beyond the scope of traditional environmental protection policies (Loorbach, van Bakel, Whiteman, & Rotmans, 2010). For example, innovation and investment policy can be designed to transform production systems for a comprehensive suite of improved outcomes, including nature protection and climate mitigation and adaptation (CBD, 2010a; Cowling et al., 2008). These outcomes would naturally include distant ones, via telecouplings [see leverage point 6]. A sustainable economy fosters technologies and associated practices that maintain, enhance and apply ecosystem services and biodiversity. This might take the form of nature-based solutions and galvanizing private investment in nature and its public benefits (Brown & Garver, 2009; Olmsted, 2016) [levers A–E]. Effecting this leverage point change would have the effect of ensuring responsible production, one part of UN SDG 12 (Responsible consumption and production).

> Technology is routinely identified as needing to become more benign in targeted ways (e.g. low-emissions fuels), and innovation is generally regarded as uniformly positive (de Coninck et al. 2018; IPCC 2018). In contrast, this treatment recognizes the many negative externalities of technological innovation as currently practiced. Thus, we avoid calling for particular technologies and innovations, and rather call for transformation of regimes of innovation, regulation and investment. Only such systemic change can ensure that technology and its use addresses negative environmental externalities comprehensively and adaptively.

3.2.8 | Leverage point 8. Education and knowledge generation and sharing

Promoting knowledge generation and sharing in general, and particularly via learning and knowledge systems for sustainability, is central to sustainable pathways. Education and knowledge transmission are often heralded as a necessary albeit insufficient route to sustainability via maintenance or change in behaviours and attitudes, but their role in sustainability can be even more fundamental, as a precursor to well-functioning societies (Sachs, 2015). Furthermore, education will only serve either role if conceived much more broadly than as imparting information or cognitive skills. Rather, education that leads to sustainable development and enduring change in knowledge, skills, attitudes and/or values builds from existing understandings, fosters social learning and embraces a 'whole person' approach (Heimlich & Ardoin, 2008; Wals, 2007). A 'whole person' approach emphasizes social and emotional capacities along with technical skills more obviously related to labour productivity (Podger, Mustakova-Possardt, &

Reid, 2010; Seligman & Adler, 2018). For instance, environmental education can enhance connectedness, care and kinship (Britto dos Santos & Gould, 2018)—relational values that have multiple benefits for people and nature (Chawla, 2009; Jax et al., 2018; Mayseless, 2015; West et al., 2018; Zylstra, Knight, Esler, & Le Grange, 2014). Similarly, transmission of Indigenous and local knowledge can serve all the roles above, including maintaining invaluable knowledge and experiences about ecological processes, but it is also a keystone to cultural integrity and the maintenance of collective identity (Turner, 2005, 2014). Societies with well-developed individual psychosocial skills, including empathy, resilience and ethical values, are more likely to have the capacity for civic engagement and to support the collective solutions, individual sacrifices and management necessary for sustainable development (Orr, 2004; Sachs, 2015). Thus, what is called for here is not simply more education of any kind, but rather a nurturing of knowledge transmission and education systems for sustainability in both management and citizenship (Orr, 2004; Tábara & Pahl-Wostl, 2007). Knowledge generation is crucial for adaptive decision-making [lever D], effective, efficient and equitable laws, regulations and policies [lever E] and progress.

> In contrast to the common calls for targeted education to address particular environmental challenges, this paper's focus on long-term pathways takes a broader view more common to educational studies, political philosophy and developmental economics to emphasize the crucial role of well-designed knowledge and education systems for enabling active citizens and good governance (Biesta, 2016; Bobba & Coviello, 2007; Olssen, Codd, & O'Neill, 2004; Tàbara & Chabay, 2013).

3.3 | Levers: Actions and interventions promoting transformative change

3.3.1 | A, Incentives and capacity building

Achieving the SDGs, the anticipated Post-2020 Biodiversity Framework and the Paris Agreement on Climate will likely require a continued evolution of subsidies and incentive programmes—coupled with capacity building—to foster conservation and stewardship practices while cultivating appropriate norms and values. Incentive programmes were featured in most scenario and pathways (Aguiar et al., in review) and can be part of effective policy mixes, involving both positive and negative incentives via regulations and market-based instruments (Barton et al., 2014; Bennear & Stavins, 2007; Porras, Chacón-Cascante, Robalino, & Oosterhuis, 2011; Razzaque et al. 2019). A particularly important component will be to shift subsidies and incentives from encouraging fossil fuel use, resource extraction and material production (incidentally promoting inefficiencies and environmental impacts) to encouraging stewardship and avoiding perverse effects in terms of behaviours, norms and values (Chan, Anderson, et al., 2017; Sumaila, Lam, Le Manach, Swartz, & Pauly, 2016; Vatn, 2010). It is clear, however, that voluntary incentive programmes such as payments for ecosystem services are limited in their applicability, and constrained to where sufficient capacity exists (Wunder, 2013). As such, capacity building enables conservation and sustainable development, both on its own and by enhancing the effectiveness and equity of incentive programmes [leverage point 4] (Bennett, Lemelin, Koster, & Budke, 2012; Dougill et al., 2012; Gross, Erickson, & Méndez, 2014).

The crucial importance of incentives applies not only to extractive industries but also to all levels of society. For example, government officials (elected and otherwise) in many nations face incentives from campaign finance and bribes that favour actions to promote extractive industries, despite their negative environmental and social effects. Reforming incentives in politics and governance [this lever] and ensuring the rule of law generally [lever E] are thus key to enabling progress at various leverage points and via all five levers.

> In contrast to the popularity of voluntary incentive programmes for addressing social–ecological problems, this analysis is not a call to scaling-up such costly programmes. Rather, it recognizes that such voluntary programmes are too often 'band-aid' efforts to address large negative externalities driven by unsustainable systems of extraction and production fuelled by perverse subsidies (Myers, Kent, & IIfS. Development, 2001; Sumaila et al., 2016). Thus, it calls for large-scale subsidy reform to 'get the incentives right'. Whereas incentives and capacity building are often seen as alternatives (Ferraro & Kiss, 2002), here we treat them as inseparable, both because effective incentive programmes can have a substantial capacity-building element (Wilcove & Lee, 2004) or depend on sufficient pre-existing capacity.

3.3.2 | B, Coordination across sectors and jurisdictions

Integrating management across administrative silos and regions is widely recognized as an important mechanism to realize co-benefits and avoid trade-offs among competing sustainability goals and objectives (Aguiar et al., in review). Achieving multiple SDGs, biodiversity targets and Paris objectives demands policy coherence (Nilsson, Griggs, & Visbeck, 2016) and the mainstreaming of environmental objectives across institutions within and among jurisdictions. For oceans, this means simultaneously managing fishing, transportation, shipping, oil & gas and renewable energy sectors, and doing so across provinces/states, nations and regions. In this sense, ensuring consistent incentives across multiple levels of governance (e.g. local including traditional, provincial, federal, regional) is also key (Kemp et al., 2007). Not all action toward a given objective will simultaneously benefit all other objectives, so

an integrated approach enables harmonization that achieves multiple targets (McLeod & Leslie, 2009). Additionally, achieving global objectives will take cooperation among disparate governing bodies (Chester, 2006; Karlsson-Vinkhuyzen, Kok, Visseren-Hamakers, & Termeer, 2017).

> While levers B, C and D each have literatures of their own, the set has been communicated together under the guise of ecosystem-based management or the ecosystem approach to management (McLeod & Leslie, 2009; Waltner-Toews, Kay, & Lister, 2008). However, because those terms are abstract and ambiguously interpreted (Arkema, Abramson, & Dewsbury, 2006), and because all three levers are important and fall into the category of widely endorsed but rarely implemented (Rosenberg et al., 2009; Ruckelshaus, Klinger, Knowlton, & DeMaster, 2008), we maintained all three.

3.3.3 | C, Pre-emptive action

Sustainable pathways generally entail addressing emerging risks in a precautionary or pre-emptive way, which may be well before system-specific proof of impact has been established. This may entail imposing constraints to slow rates of change in natural systems or resources, or to cap the scale of changes, in the absence of precise knowledge of causal relationships or maximum allowable change in those relationships. Social–ecological systems frequently involve phase shifts that are difficult to predict (Rocha, Peterson, Bodin, & Levin, 2018) or reverse (Folke et al., 2004; Leadley et al., 2014; Walker & Meyers, 2004), and for which it is difficult to determine the key driving forces in advance (Burgess, Polasky, & Tilman, 2013; Hastings & Wysham, 2010; Levin, 1992). Moreover, there is often a long time-lag between scientific attention to a phenomenon and consensus about causality (let alone proof; Ludwig, Hilborn, & Walters, 1993; Oreskes, 2004), such that phase shifts can be better prevented and managed via proactive and precautionary approaches.

> As above (lever B), this lever is rarely implemented, likely because precaution is often seen as at odds with evidence-based decision-making (Mason-Renton, Vazquez, Robinson, & Oberg, 2019), and because pre-emptive action entails costs and foregone profits, which appears inefficient in the short term. This analysis sides squarely with the many calls for management for the long-term and which reflects the realities of complex social–ecological systems. Again, the COVID-19 pandemic exemplifies the importance of pre-emptive action, as relatively modest investments in conservation, monitoring and surveillance could potentially have prevented or reduced the multi-trillion dollar costs of the pandemic.

3.3.4 | D, Adaptive decision-making in the context of resilience and uncertainty

Policies, programmes, bottom-up initiatives and management agencies that seek optimal outcomes while assuming linear or equilibrium ecosystem dynamics are likely to result in undesirable surprises, as nature often operates in nonlinear ways (Chapin, Chapin, Kofinas, & Folke, 2009). Policies, programmes and initiatives may be more effective in the long term if designed as follows: to be robust to uncertainty (performing well across variation in both ecological and socio-economic dynamics); to learn and adapt (despite potential inefficiencies); and to cultivate system resilience to maintain critical functions in the face of disturbance and change (e.g. via diversity and redundancy; Folke, Hahn, Olsson, & Norberg, 2005; Levin & Lubchenco, 2008; Tàbara et al., 2010; Walters, 2002). Where ecosystems have been degraded (Jackson et al., 2001), investing in their rehabilitation and transformation can in many cases pay substantial dividends (Lorimer et al., 2015; Pringle, 2017). In many contexts, retaining and enhancing ecological diversity can guard against shocks and help maintain ecosystem services (Oliver et al., 2015).

> As above (levers B and C), this lever is rarely implemented despite its strong and long-standing scientific basis (Walters & Hilborn, 1978). It remains important. Whereas adaptive management is often understood as being learning (about ecosystems) by doing (Berkes et al., 2003), here we side with those from management and other social literatures who emphasize that the needed learning is also social learning towards sustainability—learning about ourselves, our institutions and our processes in the context of complexity and ecological limits (Chapman, LaValle, Furey, & Chan, 2017; Lee, 1994; Tábara & Pahl-Wostl, 2007).

3.3.5 | E, Environmental law and implementation

Consistent enforcement of laws (including those governing rights and responsibilities, that is, strong rule of law) is a vital prerequisite to reducing the deterioration of nature and protecting human and ecosystem health (Morita & Zaelke, 2005; Schmitz, 2016; Wang & McBeath, 2017). Rule of law is thus key for protecting the rights of the public and future generations from incursion by private interests. Stronger international laws, constitutions and domestic environmental law and policy frameworks, as well as improved implementation and enforcement of existing ones, are key for protecting nature and its contributions to people (Boyd, 2011; Suckling, Greenwald, & Curry, 2012; Westwood et al., 2019). This is particularly true for vulnerable and marginalized populations who bear a disproportionate share of the burden of adverse environmental impacts (e.g. pollution) and are more likely to lack access to basic environmental services (e.g. clean water and adequate sanitation). Respecting differences in context, much can be learned from legislation, policies and instruments

with demonstrated successes, while still maintaining opportunities for regulatory experimentation and innovation (Evans et al., 2016; Hutchings, Stephens, & VanderZwaag, 2016; McDonald et al., 2015).

> In many nations, strong environmental legal frameworks have been and continue to be weakened in favour of neoliberal and voluntary approaches (Pellizzoni, 2011). This analysis sides with the abundant environmental legal scholarship demonstrating the importance of regulations, also for structuring voluntary approaches (Bean, Bonnie, & Wilcove, 1999; Bonnie, 1999). Beyond calling out problems of corruption, this analysis points to the foundational role of strong, functional government institutions (e.g. courts, independent judges) and consistent enforcement of laws (UN Environment, 2019a, 2019b).

4 | DISCUSSION

While each lever and leverage point contains claims that are now familiar, our contribution is to provide a first comprehensive and rigorous articulation of a set of elements for transformative change towards sustainable pathways, including a discussion of the facets of each lever and leverage point and possible interrelationships between them. In some cases, individual leverage points have innovative aspects (e.g. 3, latent values of responsibility). In other cases, novelty stemmed from combinations of ideas (e.g. lever A, where we packaged incentives within a call for broad subsidy reform). While no single lever or leverage point is wholly novel, such is the nature of knowledge synthesis, where the novelty is at a coarser level, in tracing the origins and uptake of ideas across literatures, and—most importantly—in the connections between various levers and leverage points in the set. While there have been efforts to identify similar points of intervention for global climate solutions (Farmer et al., 2019; Otto et al., 2020; Tàbara et al., 2018), we know of no similar efforts for the biosphere including climate and aspects of sustainable development.

Given the diversity of intervention options and the scale and complexity of the problem, there is no objective way to categorize or verify levers and leverage points. As such, the set identified here should be taken for what it is—one comprehensive effort that stemmed from a thorough scenario and pathway analysis (detailed in Aguiar et al., in review) and the combination of the authors' many years of experience culminating in an iterative group process and associated literature review. Others doing the same exercise might well have expressed levers and leverage points in different terms, and they may have identified additional levers and leverage points or overlooked some of these, particularly those that were largely implicit in scenarios. However, we are confident that those we have identified are meaningful and important. The set here is consistent

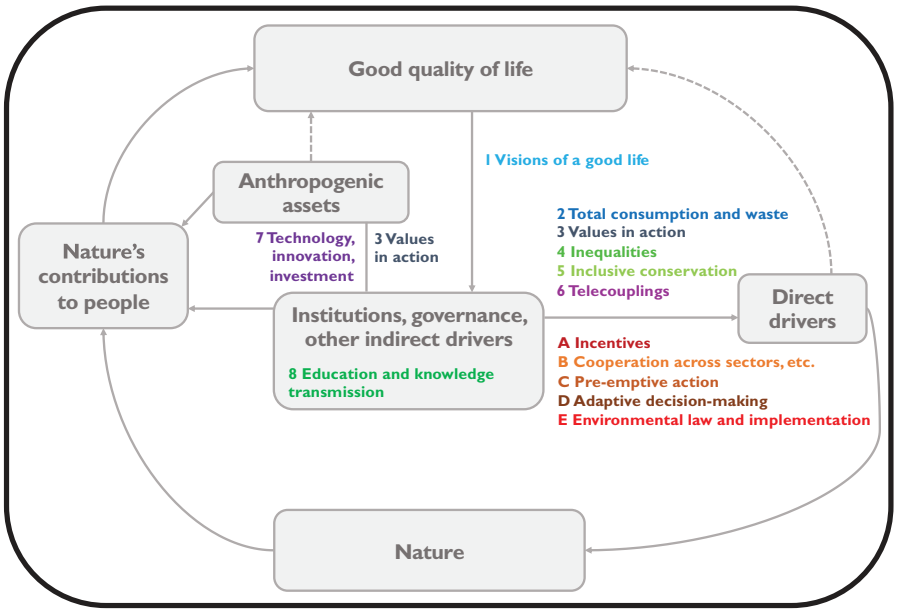

FIGURE 3 Eight featured leverage points and five levers of transformative change towards sustainable pathways, overlaid on a simplified version of the IPBES Conceptual Framework (graphical details are depicted slightly differently to accommodate the levers and leverage points, which are themselves represented in short form for graphical simplicity; Díaz et al., 2015). The leverage points (1–8) and levers (A–E) are placed at their primary sites of action, where relatively small changes in indirect drivers could influence other elements to effect large changes in outcomes for nature and its contributions to people. Although the leverage points and levers vary in many dimensions, all pertain somewhat to institutions (both formal and informal), and in most cases how these institutions influence other elements of the Conceptual Framework (including 1 Visions of a good life, where the change would originate with institutions). Many levers and leverage points could be situated within 'Institutions, …', but most do pertain especially to direct drivers—including 'Technology, …', which has impact via Anthropogenic assets. 'Values in action' occurs in two places, affecting human action in the Direct drivers via 'Institutions, …' and also 'Anthropogenic assets' (e.g. infrastructure). Colours correspond to those in Figure 4

with the Global Assessment's Summary for Policymakers (IPBES, 2019a, 2019b), which was approved by IPBES' 132 member nations.

While all levers and leverage points address indirect drivers, they do so in ways that affect different elements of social–ecological systems, and different components of the IPBES Conceptual Framework (Figure 3). The five levers are applicable broadly (not only at the eight leverage points), and desired changes at the leverage points might require additional policy tools or intervention approaches (not only the levers). As such, this analysis offers a prioritization of several key approaches and points of intervention, not a comprehensive treatment of every action that might or must be taken. Pathways to sustainable futures involve considerable flexibility in how to promote positive changes in leverage points such as consumption or inequalities, which would entail substantial variation across contexts (Chan et al. 2019).

Although we were inspired by and benefited greatly from Meadows (1997), our levers and leverage points do not conform to her typology or its derivatives (Abson et al., 2017; Meadows, 1997). This divergence was intentional, because these typologies did not seem well suited to our context of complex, multiscalar global social–ecological systems, which have not one purpose but rather a collection of contested ones favoured by different agents of change. Thus, while some levers and leverage points map onto Meadows' hierarchy, others do not. For example, incentives (lever A) and law and policy (lever E) are clearly both 'Rules', but levers B–D (integrated, pre-emptive and adaptive decision-making) are not cleanly any of Meadows' key concepts, and yet they are key (they are 'Paradigms', 'Delays', 'Balancing Feedback Loops' and 'Information Flows', but also more than that—they are the manner in which decisions are made). In general, Meadows' typology does not seem well suited to contexts of adaptive management, where decisions are not simple products of rules nor of feedback loops. Furthermore, values (leverage point 3) defy placement: they cannot be reduced to 'Goals' because in Meadows' typology, those pertain to 'the purpose or function of the system' (Meadows, 2009, p. 41). In general, Meadows' typology also does not seem well suited to social systems, where individuals and groups have competing and evolving purposes. Thus, while we and many others have found great value in Meadows' typology for insights into systems, it is not clear that it is the most useful framework for guiding social–ecological practice and policymaking.

4.1 | From levers and leverage points to real change

Although these various actions and changes may seem daunting when approached separately, one action may remove barriers associated with another, potentially having mutually reinforcing positive effects. There are many possible synergies, depending on context and implementation; Figure 4 depicts one possible pathway by which different levers and leverage points might enable others. Accordingly, and perhaps counter-intuitively, multiple actions may feasibly be achieved together, as illustrated by a series of specific, national examples of innovation (Chan et al. 2019), each of which may provide a path that other nations might follow. There are also examples of important regulatory interventions operating at local and regional scales, in different manners. Boxes 1 and 2 describe just two nation-scale examples of isolated successes (not the complete realization of utopian visions).

4.2 | Initiating transformations, building support

The joint product of effectively applying the levers and leverage points is a global sustainable economy—that is, an economy that is sustainable at all scales, including planetary ones. It would entail large-scale legal reform across many jurisdictions to achieve a renewable-based, low-impact circular economy. That is, an economy in which wastes are used as resources and goods are repaired and reused, but also one where extraction, production and processing have at most small negative impacts on nature and its contributions to people, and where these impacts would in turn be mitigated. Although the IPBES Global Assessment's Summary for Policymakers (IPBES, 2019a, 2019b) boldly seeks such a future, its approval does not itself entail that reform. As such, much of the work of transforming towards sustainability will need to first build political support at a range of scales. In the cases described above (Boxes 1 and 2) and others in Chan et al. (2019), political opportunity was created in part by various actors intervening in creative ways to enable broad and focused public support. By leveraging further corporate and government action, individual and local efforts might be scaled up to transformative change for sustainability, and these can be initiated by the private sector, civil society and governments at all scales.

Many initiatives already address the aforementioned leverage points and levers, at least partly (Bennett et al., 2016). Analysing these initiatives using the levers and leverage points lens may highlight system components and changes not usually addressed, which might facilitate transformative changes towards sustainability. For example, there is a great deal of attention to reforming investment and technological innovation for a low-carbon economy (e.g. via carbon pricing), but few efforts simultaneously internalize comprehensive impacts on nature and its contributions to people—as suggested above [six externalities and telecouplings, seven technologies, innovation and investment; throughout this section, in square brackets, numbers 1–8 pertain to leverage points and letters A–E to levers]. Addressing the leverage points partially (e.g. only carbon as but one externality) can be counterproductive, for example, potentially incentivizing other kinds of externalities and impacts on nature including via land use change, water quality and quantity and soil retention (e.g. Díaz et al., 2019; Hof et al., 2018).

Three apparent gaps in current efforts deserve mention. First is the relatively limited role that values have played in sustainability initiatives to date, despite the potentially transformative role of values throughout a variety of levers and leverage points. Yet this is not primarily a story of value change, but of incorporating and aligning with existing values. This process is likely to begin with identifying the diverse relational values that people already hold (principles, preferences and virtues about relationships involving nature) that are conducive to sustainability, and designing infrastructure and

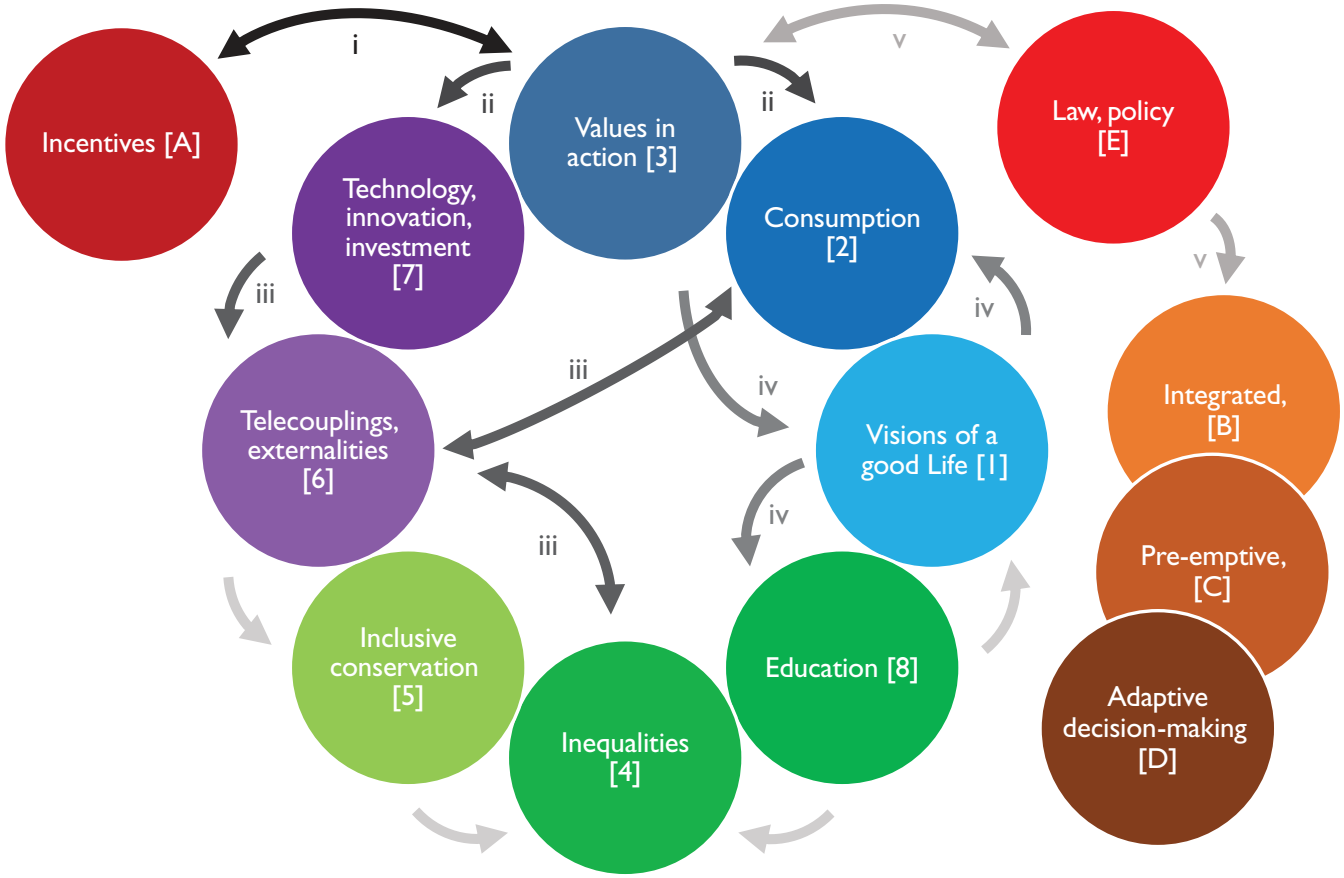

FIGURE 4 One hypothetical causal chain of how the leverage points and levers could coproduce a global sustainable economy [1–8 refer to leverage points, and A–E refer to levers]. First, **(i)** a new **incentive** programme [A] provides a means for individuals and organizations to express their latent **values** of environmental responsibility [3] by paying for diverse resource users and land/water stewards to conserve and restore ecosystems, mitigating unintended negative environmental impacts associated with supply chains. These co-payments thus provide **incentives** that enable additional **value-oriented action**. **(ii)** Both the consumer/organizational **action** and the new conservation/restoration trigger [7] **innovation** in practice and appropriate **technology**. The consumer/organizational action of committing to pay for mitigation of their impacts might have the effect of [2] reducing **consumption**. **(iii)** Both the innovation and the reduction in consumption rein in [6] negative environmental **externalities**. Because many negative externalities have disproportionate impact on vulnerable populations, this could [4] reduce some **inequalities**. **(iv)** As a socially conspicuous way for people to enact latent values of responsibility, the practice becomes normal and helps shift (1) **visions of a good life** away from conspicuous consumption. This further [2] reduces **consumption** and enhances [8] **education** about social–ecological problems, systems and solutions. **(v)** The **value-enabled action** may then facilitate changes in [E] **laws and policies**, and their enforcement, with four effects: [3] consolidating value-based action; [B–D] shifting management and governance systems to be **integrated**, **pre-emptive** and **adaptive**; further increasing [8] **education** and knowledge transmission about nature and sustainable resource use; [5] enhancing broad and appropriate **inclusion** of Indigenous Peoples and Local Communities in conservation and restoration; and [1] eliminating harmful production–enhancing **subsidies/incentives** (last two arrows not shown for simplicity). Unlabeled silver arrows depict a small subset of additional synergies by which one leverage point might facilitate others

institutions—including rules and laws—to allow the full expression and growth of those values. These values include diverse ideals of sufficiency at the centre of *notions of a good life* that do not entail continually increasing *consumption* [leverage points 1, 2]; notions of *equity* [4] and responsibility for impacts, even if delayed, diffuse and distant [*externalities*: 6]; the diverse values of responsibility that are central to enabling new *social norms and action* for sustainability [*values in action:* 3] including through *incentives* and regimes of *innovation, technology and investment* that align with those values [lever A, leverage point 7]; and the local values consistent with conservation, which enable appropriate *involvement of Indigenous Peoples and local communities in conservation* [5]. *Education and knowledge generation and sharing* are key for appreciating diverse values, which are embodied in the diverse *knowledge systems* that deserve to be maintained [8].

As one example of the limited role of values to date in sustainability initiatives, many behaviour-change programmes encounter one of two major obstacles to fostering system transformation. First, campaigns often appeal only to a small minority of self-identified environmentalists based on a narrow set of environmental values (Moisander, 2007). This can impede behaviour change among broader publics due to negative stereotypes and the narrow reach of social norms (Chan, Anderson, et al., 2017; Chan, Olmsted, et al., 2017). Second, broad systems of taxation or incentives often lack a

BOX 1 Namibia

Namibia's relative success with community-based conservation illustrates many of the above levers and how they can work together. In 1996, Namibia's newly independent government passed progressive legislation that devolved user rights regarding nature (in particular wildlife) to local communities, consistent with its constitutional framework for nature protection (Chapter 11, Article 95-l) [E, law; 5, involving local communities]. This change in governance allowed communities to register their traditional lands as communal conservancies, restoring both their legal right and legal responsibility to manage customary landholdings for the sustainable flow of benefits from wildlife and other natural resources. The proliferation of conservancies—from 4 in 1998 to 86 in 2019—has resulted in increased levels of financial benefits to the rural poor (Jones, Davis, Diez, & Diggle, 2013; Naidoo et al., 2016), recovering populations of wildlife (Naidoo, Weaver, De Longcamp, & Du Plessis, 2011), a tremendous increase in the amount of land under conservation management to over 40% (MET/NACSO, 2018) and the reconnection of a link between Indigenous Peoples and wildlife that spans thousands of years of joint history [2, visions of a good quality of life]. Governance decisions were the overall platform for the conservation successes that followed, with subsequent innovative linkages between local communities and international markets for tourism and plant products providing the tangible mechanisms by which local people have benefited from their natural resources [7, technology and innovation] (Barnes, MacGregor, & Weaver, 2002). Community-based conservation has helped take a step towards improving the dramatic inequality between the marginalized rural poor and wealthier ranchers and urbanites in Namibia [4, inequalities]. While considerable limitations and threats remain that could hamper further progress (e.g. perverse incentive structures), the successes seen in Namibia demonstrate that conservation by local communities on their lands can lead to gains both for people and for wildlife.

BOX 2 Seychelles

Seychelles is among the world's leaders in the percentage of its land that is designated as protected, at over 42% (World Bank, 2018). Seychelles amended its constitution in 1993 to recognize that citizens have the right to live in a healthy environment, and that government has a responsibility to protect the environment [E, law; 5, justice] (Boyd, 2011). In a case involving the prosecution of eight individuals for unlawful possession of meat from protected species, including sea turtles and boobies, the Supreme Court of Seychelles referred to the constitutional right in interpreting the *Wild Animals and Birds Protection Act*. The court wrote: 'The right to a healthy environment has become a fundamental right. In Seychelles that right extends to the Management of Marine Resources as well as protected Land or Sea Birds' [E, law] (Supreme Court of Seychelles & Perera, 2004). Seychelles was recognized by the United Nations Environment Program as a Centre for Excellence in its approach towards coastal development with reference to both efforts to protect coral reefs and a successful dolphin-free tuna industry [B, integrated management; D, managing for resilience] (CountryWatch, 2018). In 2018, Seychelles announced two new marine-protected areas totalling 210,000 square kilometres, made possible through debt restructuring and the collaboration of foundations, seven national governments and several UN agencies [A, incentives and capacity building; B, integrated management].

broad base of support, or conflict with existing attitudes and values. This can backfire due to widespread resentment and/or non-participation (Chan, Olmsted, et al., 2017). Instead, we see an opportunity in programmes and approaches that seek to enable legal change first by leveraging widely held but latent values of responsibility into new social norms in environmental (and social–ecological) contexts, perhaps by empowering many people to act in accordance with those values—easily, enjoyably and inexpensively [3].

The second gap is the ongoing need for the broadscale reform of subsidies and incentives [A], which have structural effects. One important step would be to extend the modest progress made with carbon pricing (World Bank 2015), in several ways. These would include advocating for and ensuring that carbon prices permeate supply chains and cross-border trade (Fischer & Fox, 2012; Jaccard, 2020); extending beyond carbon to include water (Molle & Berkoff, 2007), land use or conversion and other metrics of damage or threat to nature and its contributions to people; and ensuring that incentive programmes are designed to foster relational values, not just 'buy' behaviour change (Chan, Anderson, et al., 2017; Chan, Olmsted, et al., 2017). Moreover, across many nations, there is disproportionately little effort to take stock of and address the perverse ecological impacts of subsidies on production and consumption despite commitments to do so through international agreements, for example, Aichi Biodiversity Target 3 of the Convention on Biological Diversity (Butchart et al. 2019). However, because of the opposition that often arises in response to such policy reform, in many contexts, policy progress may rely upon first laying the groundwork by enabling the widespread expression and reinforcement of values that support the reform [leverage point 3] (see also third gap). Another potentially effective approach is to apply implicit carbon prices through market-based regulations that combine the strengths of economic instruments and command and control regulations [levers A and E] to deliver sustainable outcomes without provoking broad public opposition.

Examples include renewable electricity mandates for utility companies or zero emission vehicle mandates for automobile manufacturers.

The third gap identified is the little attention paid in practice to structuring governing institutions so that they are coordinated, adaptive, precautionary and addressing the resilience of social–ecological systems [B, C, D]. Of particular relevance is aligning governance structures to promote consistent goals, especially transformation, which is generally opposed by powerful interests vested in the status quo (e.g. fossil fuel companies lobbying and marketing against climate policies). Multi-stakeholder non-governmental organizations—as associated with certification systems—offer some promise to leverage change within commodity sectors (e.g. palm oil, soy, cotton, rubber and fisheries), provided power inequities are addressed (e.g. so that smallholders have a substantial voice) and consumers are enlisted effectively. Another option is to preclude powerful vested interests from directly participating in policy development. For example, the World Health Organization Framework Convention on Tobacco Control requires governments to exclude tobacco companies from involvement in formulating tobacco control policies. A key enabler of all three of these levers is transparency: without available and reliable information, one cannot have governance that effectively crosses jurisdictions (as in supply chains, Nyström et al., 2019), addresses emerging risks and adaptively navigates uncertainty and complex dynamics (Razzaque et al., 2019). Broadly, such structural changes in *how* we govern can be fundamental and thus especially promising targets for advocacy and intervention, recognizing that change may take persistent and prolonged engagement.

Much writing about sustainability and even about transformative change might lead one to believe that transformative change to sustainability is as simple as scaling-up and out existing sustainability initiatives. Perhaps as a community of environmental and sustainability professionals, we have been too wary of disappointing those who are seeking sustainability by acting locally via incremental change in business or policy. The IPBES Global Assessment made it clear that neither transformative change nor sustainability is so easily achieved. This analysis of levers and leverage points extends that assessment, building upon its framework for concerted structural change that could actually bring about harmony with nature and the 'future we want'.

5 | CONCLUSION

The approach presented here, using the language of levers and leverage points, provides a framework for imagining pathways to sustainability in the context of complex, multidimensional global futures, where uncertainty is extreme and accurate predictions are not feasible. Although there is no objective means of identifying or validating levers or leverage points at the global scale, we hope that this intensive, systematic synthesis effort will enable innovation in policymaking and interdisciplinary research for sustainability. For policymakers, this paper builds upon and complements the IPBES Global Assessment in offering a foundation for prioritizing efforts across sectors and government agencies in pursuit of the recognized need for transformative change. For researchers, we offer a deeply interdisciplinary synthesis that provides a starting point for assessing pathways towards a sustainable future.

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CONFLICT OF INTEREST

Kai Chan is a Lead Editor at *People and Nature*, and Eduardo Brondízio, Rachelle Gould and Barbara Muraca are Associate Editors. None of us had any involvement with the assessment of this article.

AUTHORS' CONTRIBUTIONS

K.M.A.C. coordinated the paper and wrote first drafts of most sections, distilling and revising longer text from the IPBES Global Assessment Chapter 5 and drafting new sections; D.R.B., R.K.G., J.J., J.L., B.M., R.N., P.O., T.S., O.S., G.G.S. and R.S. contributed substantial text about the levers and leverage points, which formed the basis for this paper; G.G.S. also helped write the Methods; A.K.B., J.A., A.P.D.d.A., D.A., L.B., C.B.-L., W.W.L.C., J.D., E.J.G., S.H., G.C.H.P., T.H., M.K., A.A.A.M., M.M.-H., P.O., A.K.S., R.S., B.S. and D.X. contributed to the nexus analysis of scenarios, and A.P.D.d.A., J.J., M.K. and R.S. reviewed the five conceptions of transformative change; H.E. helped design figures; All aforementioned authors contributed to the expert process for identifying levers and leverage points; H.T.N., S.D., J.S. and E.S.B. contributed to broader design. All authors also edited the text.

DATA AVAILABILITY STATEMENT

As a review-based analysis, this article does not include data.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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