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Making Sense of Resilience

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Abstract: While resilience is a major concept in development, climate adaptation, and related domains, many doubts remain about how to interpret this term, its relationship with closely overlapping terms, or its normativity. One major view is that, while resilience originally was a descriptive concept denoting some adaptive property of ecosystems, subsequent applications to social contexts distorted its meaning and purpose by framing it as a transformative and normative quality. This article advances an alternative philosophical account based on the scrutiny of C.S. Holling's original work on resilience. We show that resilience had a central role among Holling's proposals for reforming environmental science and management, and that Holling framed resilience as an ecosystem's capacity of absorbing change and exploiting it for adapting or evolving, but also as the social ability of maintaining and opportunistically exploiting that natural capacity. Resilience therefore appears as a transformative social-ecological property that is normative in three ways: as an intrinsic ecological value, as a virtue of organizations or management styles, and as a virtuous understanding of human–nature relations. This interpretation accounts for the practical relevance of resilience, clarifies the relations between resilience and related terms, and is a firm ground for further normative work on resilience.

Keywords: resilience; robustness; antifragility; lock-ins; efficiency; sustainability; ecosystem science; environmental management; normativity

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1. Introduction

Today, resilience is the cornerstone of important initiatives, addressing risks like climate change, most prominently in cities [1,2] and developing countries [3]. Many influential frameworks and policy documents frame resilience as a positive response to shocks and stresses and as a legitimate goal for urban transformation, which overlaps closely with sustainability [4]. Recently, however, authors from the Resilience Alliance disputed this vision on the grounds that resilience is a descriptive term from complex systems theory, while sustainability, instead, is a moral term [5].

This thesis is surprising. If resilience was non-normative, why should anyone care about building or maintaining it? Further, if resilience and sustainability are not synonyms, how do they relate? These puzzles add to long-standing debates on the elusiveness of resilience [6,7], its dubious moral implications [8–12], and its unclear relations with competing concepts [13–17].

Here, we object to the Resilience Alliance's arguments with an alternative philosophical account of resilience and its practical significance. We start by discussing some problems around the interpretation of resilience and motivating a close scrutiny of C.S. Holling's original work on the concept (Section 2). We then carry out this scrutiny in two sections. First, we examine Holling's critiques of traditional ecological practices and his ideas for reforming them, emphasizing the various roles resilience takes on in these contexts (Section 3). Then, based on this analysis, we advance our unified account of resilience in critical dialogue with the "official view" of the Alliance (Section 4). We argue that resilience always is a normative concept. One can use it as an instrumental value, closely related to various stability concepts; yet, as we show, Holling's resilience is best seen as an intrinsic ecological value, a critical tool, and an alternative to efficiency, rigidity, and instrumentalism in design, management, and governance. The conclusion stresses the relevance of our results by mentioning some consequences of interest for scholars and practitioners in resilience and related areas (Section 5).

2. Framing Resilience

The Resilience Alliance is the single most influential research cluster in the field of resilience research, and its contribution to the popularization and institutionalization of resilience cannot be minimized. Nonetheless, we disagree with the philosophical characterization of resilience that the Alliance has promoted of late, and, in this paper, we develop an alternative account that, in our view, is more practically sound.

This section discusses some key concepts and ideas about resilience for the purpose of problem framing. We begin by engaging with some representative articles and samples of work in the broader resilience field, first by presenting categories and ideas commonly used for interpreting resilience (Section 2.1), and then by using these categories to characterize other concepts that have been compared with resilience (Section 2.2). These discussions are neither exhaustive nor intended to be systematic reviews, but to act as introductions or guides to the main elements that constitute the Resilience Alliance's view on resilience, as well as the alternative we propose. Then, we produce a succinct description of the Resilience Alliance's "orthodox narrative" on resilience, and explain our approach for contesting it (Section 2.3).

2.1. Interpreting Resilience: Problems and Perspectives

After being extensively discussed in 1970′s psychology and ecology, resilience is now found in many disciplines [18,19]. Despite an abundance of work on how to interpret this term, many doubts persist. Here, we review some.

Scholars often ask, for example, if resilience is an outcome, or instead a process or ability. Here, we assume that resilience is both things, since it has ex-ante and ex-post aspects [7]. Definitions commonly portray it as an outcome: a type of response to change. This aspect allows us to identify (un)resilient things, but only after disturbance (ex-post). However, resilience also is an ability that enables things to display resilient outcomes. This ability is expressed in terms of resilience determinants that characterize (un)resilient things before disturbance (ex-ante), and that are key for designing or managing resilience.

Given these considerations, we can regard resilience as a polysemic term, i.e., one that designates many distinct concepts [7]. Resilience scholars find that resilience concepts differ ex-ante, ex-post, and in their normativity.

First, resilience concepts vary ex-ante by domain, because resilience determinants differ across systems and entities. Psychological resilience, for example, lies in a combination of mental abilities and social protective factors [20]. In contrast, while system views (those more influenced by ecology) usually mention determinants like redundancy or diversity of responses, cross-field comparisons show that these determinants also vary a lot across domains [19,21,22].

Second, there are various views on what kind of response resilience is ex-post. As others note, "[r]*esilience* is a loosely organized cluster of concepts each one related to some aspect of the interplay of transformation and persistence" [23] (p. 1). Authors generally distinguish three concepts where change is progressively more inherent to resilience: resilience as maintenance or recovery (also known as "engineering" resilience), as change at the margins (adaptive or "ecological" resilience), and as transformability ("evolutionary" resilience) [2,24]. Later, we return to these ideas and flesh them out further.

Lastly, views of resilience are said to differ in their normativity [6]. This is a subject where some philosophical distinctions are particularly convenient. Normativity is typically understood as a property of claims or of concepts, consisting of their capacity to guide action or to act as goals [25,26]. Statements are normative when they contain normative concepts, such as *should* or *right*. Concepts are normative when they imply evaluations or prescriptions, for instance, if they are only definable in terms of paradigmatically normative terms (e.g., *murder* is normative because murder is a *wrongful* or *unlawful* deliberate killing; *elegant* is normative because calling a dress elegant is appraising it as *good in a way* [27]). Here, we consider two kinds of normative concepts: values and virtues. Values are things, broadly speaking, that people typically pursue or avoid, while virtues (or their opposites, vices) are traits that are (un)desirable to have, for persons as well as societies or organizations. Thus, we talk e.g., of the virtues (vices) of football clubs, socialism, and so on.

Crucially, values and virtues can be intrinsic goals or ends, or instrumental ones [27,28]. A word of caution is needed about the term *intrinsic*. Some philosophers use this label to refer to ends or things whose value is self-standing or independent of anything else, including human appreciation [28,29]. Yet, this use, though popular among the critics of (the consequences of) anthropocentrism in thinking about nature, can be both theoretically overloaded and practically problematic [29]. Thus, we will talk here of intrinsic values or virtues in a second, weaker sense that is also common among philosophers [28]. In this weaker sense, *intrinsic* qualifies those ends that can be desired for themselves or as ends strictly speaking, such as e.g., equality, generosity, or wellbeing. Instrumental values or virtues, in contrast, do not express ends, but only aspects of means or processes relative to other ends. This distinction between desired ends (intrinsic) and desired aspects of means or processes (instrumental) carries a further implication. Although intrinsic ends can be undesirable for various reasons (for example: economic equality is often said to conflict with freedom, another intrinsic value), instrumental ends are peculiarly ambivalent, since they can only be desired when they warrant, or enhance, the satisfaction of intrinsic ends, and can be quite undesirable if put to ill-chosen ends [26]. For example, consider efficiency, a quintessential instrumental value. Efficient processes or procedures are those that, compared to their alternatives, obtain more of a desired result with the same means, or similar results with lesser use of those means. Efficiency is then desirable in distributing wealth, since it improves economic equality, but it makes things worse if it serves putatively wrong ends, e.g., efficient killers are worse overall than non-efficient ones.

Polysemy can raise confusion when authors do not clearly specify which concept is in use. With resilience, this is a general concern, since vague or ambiguous uses of the term are rather common [6,7]. Terms are used ambiguously if they have indistinguishable interpretations, or it is unclear which concept they designate. Vagueness is similar, consisting in an under-specification of concepts [19]. Both features are opposed to precision, and viewed as a potential hindrance to resilience scholarship and practice [6,7]. As we see next, they also complicate the task of situating resilience vis-a-vis other concepts that, in theory, relate to it in some way.

2.2. Related Concepts

The diffusion of resilience has also raised a need to demarcate this term from those that overlap or compete with it, such as adaptation [8], vulnerability [13,30], and others. Most relevant for this article are robustness, antifragility, sustainability, lock-in, and transition. Next, building on the above discussed categories, we explain these terms and establish some bases for comparing them with resilience.

2.2.1. Robustness

Robustness is discussed in fields like statistics, control theory, or engineering. It is defined, for example, as “reduced sensitivity of outputs to shocks or variations in input” [17] or as an “ability of a system to resist change without adapting its initial stable configuration” [31]. There is also work on dynamic robustness, a property of systems that absorb impacts through adaptability or reorganization [32,33]. Like resilience, then, robustness describes various kinds of responses to change (and properties that enable them).

With regards to its normativity, robustness seems to characterize things that work well, thus suggesting that it is an intrinsic value, a synonym of infrastructure safety, for instance. Yet, it can also be interpreted as simple resistance to change, and so, as an instrumental value, it is convenient when a system embeds desirable values, but problematic in other cases. In the development literature, for instance, the robustness of poverty profiles is a much-studied issue that illustrates this ambivalence of robustness [34,35]. Vernacular uses of robust have a similar normative profile: they can denote a good health (an intrinsic value), but also just a strong physical constitution (an instrumental one).

The exact relations between resilience and robustness are a matter of concern, especially in engineering. Hansson and Helgesson [36], for example, compare recovery-based resilience with a static view of robustness, arguing that both are stability concepts, resilience being an ability to return quickly to equilibrium, and robustness its limiting case (since robust systems are not displaced from equilibrium, and so their recovery time is zero). Depending on the concepts used in each case, resilience and robustness are also alternatively viewed as complementary [37], rival, or equivalent goals in infrastructure design and management [38].

2.2.2. Antifragility

Another popular notion describing a system's response to change is that of antifragility. According to Taleb [39] (p. 1), "[a]ntifragility is beyond resilience or robustness. The resilient resists shocks and stays the same; the antifragile gets better ... [Antifragile] things benefit from shocks; they thrive and grow when exposed to volatility, randomness, disorder, and stressors and love adventure, risk, and uncertainty." Taleb uses a static view of resilience here, which neglects the diversity of resilience concepts; we return to this issue later. Yet, for the moment, note the following contrast between antifragility and dynamic robustness: although both concepts express persistence through adaptability, antifragile systems are also opportunistic, or they can use change to evolve and improve. This distinction has two consequences. First, antifragility is not a stability concept [33]. Second, unlike robustness concepts, antifragility is an intrinsic value or virtue, rather than an instrumental one. We cannot help but want those things that are intrinsically able to get better, and societies or organizations with that ability are, by necessity, virtuous in some way.

2.2.3. Sustainability

In this article, we cannot do justice to the variety and richness of existing definitions and views about sustainability [40]. However, it seems safe to claim that accounts of sustainability vary in their relative emphases of two aspects that seem equally inherent to the concept: the social impacts on natural systems and their moral consequences.

On the one hand, for many ecologists and environmental thinkers, sustainability conveys the idea that certain (unsustainable) human activities threaten to create ecological crises, like climate change, biodiversity loss, or resource depletion. This idea is captured by the famous IPAT equation [41], where I stands for ecological impact, P for population size, A for affluence (resource units per person), and T the average process efficiency of technology, measured as natural impacts per resource unit. This equation therefore stresses the causes and conditions of sustainability by framing it as a tendency to keep ecological impact (I) below an ecological carrying capacity threshold ($I < ECC$).

On the other hand, sustainability is also used prominently as an adjective in the label "sustainable development" to emphasize the idea that the continuity and wellbeing of society depend on abandoning or transforming those activities, and maintaining or restoring the natural processes now endangered. This aspect is highlighted, for example, by the Brundtland definition [42], which focuses on the moral consequences of (un)sustainability while leaving its causes or conditions implicit.

Resilience and sustainability are compared on many grounds, with varied conclusions [16,24,43–45]. Building on our schematic discussion, they appear to differ in one subtle respect when both terms are taken to refer to environmental risks. Human societies or activities are sustainable if they do not create environmental risks for themselves, and they are resilient simply if their response to already existing risks has certain qualities. Thus, sustainability concerns the human origins, as well as the consequences of environmental risks; but resilience, like robustness or antifragility, refers only to this latter aspect.

While there are manifold accounts of the concept, it seems clear that sustainability is (and is uniformly used as) an intrinsic value, that is, something desirable of human activities, technology, etc., as well as a virtue of the societies or organizations that promote it.

2.2.4. Lock-In and Transition

Lock-ins are social trajectories that promote their own underlying causes while posing barriers for alternative dynamics [46]. For the purposes of our discussion, they can also be seen as institutional, technical, and cultural rigidities that typically result from technology diffusion and upscaling [47]. Transition and lock-ins relate in the following way: societies require a rapid transition to sustainability, and lock-ins are major obstacles to it. For example, climate change mitigation requires dismantling the fossil fuel industry, which, aside from its standalone impact on many economies, is heavily entrenched within other industries, technical skills, institutional regimes, behaviors, beliefs, and values, such as freedom of mobility. In other words, our societies are locked in an unsustainable trajectory, and transition would be the process of loosening ties between various facets of (unsustainable) lock-ins, while fostering opportunities for (sustainable) alternatives [48].

In the context of sustainability, then, lock-in has a negative connotation, and transition a positive one. Yet, as the above definitions make clear, lock-in expresses an ambivalent process feature: while being locked in an unsustainable trajectory is worse than simply being unsustainable, being locked in a sustainable pathway would indeed be much better than being simply sustainable. Something similar applies to transition. Therefore, the normativity of these concepts is strictly instrumental.

While transition and lock-in are not responses to change, they respectively denote system features that enable systems to adapt while impeding structural change (lock-in) and processes of structural change (transition). Therefore, they partly overlap with the concepts discussed above, namely with adaptive resilience or dynamic robustness (lock-in) and transformative resilience (transition). These overlaps have motivated much discussion on how to interpret social resilience or the resilience of sociotechnical systems in the context of sustainability transitions [14,15].

2.3. The "Orthodox Narrative" of the Resilience Alliance

Building on earlier work by ecologist C.S. Holling, since the 1990s, the Resilience Alliance has championed resilience as a more general approach for managing risks in socio-ecological and other complex systems. As we saw, they were hugely successful. Yet, their endeavor was not unopposed. In an influential paper published in *Ecology & Society*, the official Alliance publication, and a leading resilience journal, Brand and Jax [6] complained that the Alliance's broadened use of resilience had contributed to distorting the original meaning and function of the term. According to Brand and Jax, resilience originally was a precise and descriptive concept that Holling had used for challenging the received views on ecosystem stability and advancing an alternative ecological conception based on complex systems thinking. In contrast, they argued, later uses were useful for articulating public debates and governance strategies on risk, but they were also more vague, normative, and incompatible with scientific work [6].

The Alliance took note of Brand and Jax's arguments, and since then, they have been using their considerable academic influence to promote a very similar narrative. We will label Brand and Jax's view the "orthodox narrative", since it does not merely push for a specific content of resilience; it also contains a battery of arguments about how to interpret and use the concept, how not to, and why. In the last decade, for example, at least two articles by prominent Alliance authors in *Ecology & Society* have specifically engaged

Brand and Jax's arguments to advance certain theses about resilience [17,49]. Resilience is defined, for example, as a "capacity ... to absorb disturbance, reorganize, maintain essentially the same functions and feedbacks over time and continue to develop along a particular trajectory" [5] (p. 3). This is an adaptive resilience concept that explicitly excludes transformation, and that is very similar to the one proposed by Brand and Jax (see [49] for a very similar account). These articles also share an insistence in the purely scientific and non-normative character of resilience [17,49].

In addition, Elmqvist, Folke, and colleagues have also tried to position this orthodox narrative in discussions about urban resilience [5]. Their article is exemplary, because it fundamentally is an objection against the growing use of resilience as a normative term and a surrogate of sustainability in urban contexts. After presenting their account of resilience, the authors argued that resilience is non-normative because it can be desirable, but also undesirable, as occurs e.g., with resilient poverty traps and similar lock-ins [5] (p. 5). In contrast, they portrayed sustainability as a purely moral term that expresses justice in distribution and between generations, which, in their view, can only be good [5] (pp. 2–4). Similar arguments about the normativity of resilience and its contrast with sustainability can be found, for example, in [17,44,49].

This orthodox narrative has a handful of problems, however. First, as Brand and Jax argued, the Alliance itself has often employed different resilience concepts—see e.g., [23,50], which raises questions regarding their authority in banishing transformative and strongly normative uses, for example.

Second, and this point applies to Brand and Jax as well, the narrative offers a misleading view of what is normative or not, and why. Scientific and moral discourses need not be sharply disjointed, for instance. As was noted, sustainability has a scientific side besides its moral one. Similarly, these accounts all portray resilience as a morally ambivalent term and a surrogate of dynamic robustness or lock-in [5,6,17,49]. Leaving aside the scientific content of this concept, its characterization suggests that resilience is an instrumental value or virtue, and therefore is a normative term. Note that these confusions about normativity can have important ramifications for our ability to understand and assess real-world examples from a justice standpoint. For instance, the fact that some resilient societies are unjust does not mean that resilience is non-normative. Consider sustainability. Sustainability is an intrinsic (and therefore desirable) value, but sustainable societies need not be good in all respects. One example: Cuba is a top country in human development rates vs. ecological footprint [51,52], and so it gets as close to sustainability as a country can get. Yet, it is still an unjust country, at least because many Cubans cannot run for political office. This example shows not only that the orthodox view involves a problematic notion of normativity, but also that the normative profile of resilience remains poorly analyzed, and its possible implications are hardly recognized.

The following sections develop a third objection in detail. According to the interpretation proposed by Brand and Jax [6], and later sanctioned by the Alliance as what we have called the "orthodox narrative", C.S. Holling originally used resilience as a descriptive term that embodied his theoretical insights on ecosystem science. In our view, this is an overly narrow interpretation of Holling, mainly because it ignores the relevance of his contributions to management. This neglect is surprising, since Holling used to think that ecosystem science and management are essentially interwoven, and, indeed, he did not lament this feature per se, but only the specific form it took in traditional ecology. We will now show that, when Holling's work is conceived as a comprehensive project for reforming ecosystem science and management, his view on resilience no longer fits into the Alliance's orthodox narrative, and it provides us with important lessons for interpreting and using this term critically.

3. Holling's Early Work on Resilience

Commentators normally neglect Holling's work on ecosystem management and focus on his critique of classical ecosystem science [5,6,19,53]. Here, we analyze Holling's work starting from radically opposite assumptions. First, we examine the relevance of Holling's critique of environmental management in relation with his theoretical critique of ecosystem science (Section 3.1). Then, we present his proposals for reforming ecosystem science and environmental assessment and management, explaining how Holling redefines resilience in each of these areas (Section 3.2).

3.1. The Critique of Traditional Ecological Practices

We begin by analyzing Holling's critique of ecosystem science and environmental management. We will show that Holling's points on ecosystem science are partly contingent on his critique of the "pathologies" of two management styles that dominated natural resource management in the 1970s: efficiency-based exploitation and typical conservationist strategies ([54–56]). Thus, while Holling certainly rejected some assumptions of classical ecology for theoretical reasons, he also rejected those assumptions as practically dangerous, namely for underpinning management directions he considered pathological.

Holling's primary target was efficiency-based management, a management style driven by the idea that "big-is-necessary" [54] (pp. 31–33), that is, by social and economic demands of maximizing exploitation. Holling characterized this management style as one that prioritizes the ongoing extraction of a "maximum sustainable yield" (MSY) of a desired resource [57], and treats other ecological or social concerns "as constraints" or even as disturbances [54] (pp. 3, 56). For example, if one's goal is to extract an MSY of timber, then pests or forests fires are disturbances with respect to it. The usual policy then is to remove these disturbances as efficiently as possible (e.g., with pest eradication or forest fire suppression programs).

According to Holling, classical ecosystem science was informed by an "engineering" view of ecosystems that favored this management perspective [57] (pp. 1–2, 21). This engineering view influenced ecosystem science in two related ways: its stability assumptions and a strongly quantitative character. Ecosystems were viewed as devices "designed by the engineer to perform specific tasks under a rather narrow range of predictable external conditions" [57] (p. 1). They were thought to have just one equilibrium, which often was chosen pragmatically and defined in narrow quantitative terms: as a fixed set of quantities (e.g., population sizes, flow volumes, etc.) that expressed, or related directly to, desired yields (MSYs) of economically valuable resources. All significant change in these variables was believed to occur near the equilibrium [53].

For Holling, these assumptions were in part pragmatically motivated, since they made ecosystem dynamics analytically tractable (i.e., quasi-linear), thus enabling the short-term success of efficiency-based management in reducing or eliminating disturbances. Yet, he argued that, in the long run, this approach increased the probability of new, unforeseeable threats with much worse outcomes [57] (p. 14ss). For example, as forest suppression becomes efficient, it raises the volume of fuel available, eventually leading to massive, uncontrollable fires [56]. Holling thus argued that efficiency-based management suffers from the syndrome of "living dangerously" [55] (p. 7ss).

Holling paid much attention to some specific "pathologies of management" [56] that often compound to make ecosystems and society more vulnerable in this sense. His more detailed discussions on the pathologies of management [51,54,56] do not label the pathologies described. In what follows, to ease discussion, we refer to Holling's pathologies with three labels that are the technical terms normally used to refer to the processes analyzed by Holling. These are rebound effects, lock-ins, and instrumentalism. Now we will examine these pathologies, since they are keys to understanding Holling's project for reforming ecology and the role of resilience in it.

Rebound effects. Rebound effects are positive feedbacks that arise when supply crises (e.g., in extraction) are addressed with efficiency measures. When such measures increase outputs or yields while lowering exploitation or production costs, they lead to demand growth and new supply crises, which motivate further efficiency measures [58]. Rebound effects have local and short-term benefits, but their undesirable impact on e.g., energy crises or resource depletion is increasingly recognized [59–61], and Holling was one of their early critics. He explained how, after removing threats to the extraction of some resource, MSY levels can be maintained or even increased, thus posing incentives for intensifying and upscaling commercial activities in the area [55]. Some troubling consequences then follow [52]. First, rebound effects simplify ecosystems and subject them to ongoing stress, which makes them vulnerable e.g., by making critical thresholds easier to breach. Second, they promote economic globalization and centralized political control, which deteriorate information feedbacks and reduce the local sensitivity and ability to respond to changes quickly [54,56]. Third, their initial advantages make managers more confident and myopic, thus contributing to lock-in (cf. below).

Lock-ins. We already explained what lock-ins are. Holling argued that lock-ins arise in efficiency-based management because, as companies and management agencies succeed, they get bureaucratized, specialized, and dependent on ways of seeing and doing [55]. For Holling, lock-ins raise several problems. One is that they foreclose alternative management options, often irreversibly. Another is that organizations become focused on short-term results, and therefore become more rigid and less able to handle ecological crises. Further, he noted that lock-ins make management unresponsive to both the natural and social contexts; in fact, he linked them with a technocratic drift that isolates experts from affected customers and the public [55,56]. Holling added that, when ecological crises appear, this feature often contributes to a loss of public trust and growing social unrest.

Instrumentalism. Holling also lamented that, as efficiency-based management gets locked in, efficiency becomes the only goal, replacing any other environmental, social, or economic goal that might have previously guided managers. This pathology expresses what philosophers call instrumentalism or instrumental rationality: a style of reasoning and decision-making that neglects intrinsic values to prioritize instrumental ones [62] (some philosophers also conceptualize instrumental rationality more broadly, in ways that recall Holling's concerns as well, but that could distract us from the main discussion). Holling was well aware of the double-edged character of efficiency, which is often, too, the point of critics of instrumentalism: when efficiency dominates decision-making, there is no room for other important or intrinsic values, or they are lost from sight.

Holling's critique of conservationism is more schematic. He described conservationism as guided by a "small-is-beautiful" worldview that stresses natural limits and strives for ecological "purity and constancy" [54] (p. 9). Holling linked this attitude to a view of nature as "ephemeral" or "mischievous" [54] (p. 31), which, notably in developed countries, "reacts against past emphasis on growth and social and economic issues" with unconditional protection policies [54] (p. 6). His concern was that, in practice, this policy also aimed at stabilizing ecosystems, which, for him, was not ecologically sound [54] (pp. 34–35). He also rejected the "popular rhetoric of ecology that everything is intimately connected to everything else," which leads technicians "to measure everything, hence producing the indigestible tomes typical of many environmental impact statements" and motivating "arbitrary, inflexible, and unfocused" policies [54] (p. 6). For such reasons, he thought that conservationism could be even more rigid and bureaucratic than efficiency strategies, and indeed more likely to aggravate lock-ins by furthering social conflict and raising "gridlocks" for economic and conservation efforts [56] (p. 332).

So, to summarize, Holling was quite unsatisfied with the ecosystem management styles of his time and their common theoretical basis. These concerns were to some extent epitomized by resilience, which was then commonly defined as the "speed of return of variables towards their equilibrium following a perturbation" [63], that is, as a sort of efficient recovery. For Holling, this concept of "engineering resilience" [64] implied a belief in a "Benign Nature" that was "infinitely forgiving", because "if a disturbance is removed, the system will ultimately return to its original condition" [54] (p. 30). It also implied that ecosystem responses to efficiency measures were themselves smooth, efficient, and easily quantifiable. In short, engineering resilience illustrated the stability basis of ecosystem science, while also acting as a goal that could complement efficiency-based management or misguided conservationist efforts.

3.2. The Reform of Ecological Practices

Now we turn to discussing Holling's ideas for reforming ecosystem science and environmental assessment and management. Table 1 offers a non-exhaustive list of proposals in each of these domains (resilience is not included, but its important role among these ideas is described in the text as well). Let us consider these proposals in turn.

Table 1. Holling's proposals for reforming ecological practices.

Ideas for Ecosystem Science	Guidelines for Environmental Assessment and Management
	I. Punctuated uncertainty
	II. The rule of hand
1. Lumpy, hierarchical ecosystem structure	III. Integrate values
2. Extended keystone hypothesis	IV. Flexibility and anti-irreversibility
3. Multi-stability	V. Opportunistic, experimental approach
4. Punctuated equilibrium dynamics	VI. Safety margins, avoid subsidies
5. Irreversibility	VII. Design with nature
6. Novelty emerges far from equilibrium	VIII. Tightening feedbacks
	IX. Regional scale
	X. Decentralized and participatory

3.2.1. Resilience and Ecosystem Science

Starting with his insights on ecosystem science, Holling thought that many ecosystems had features related to their complexity, which called into question the assumptions of stability and quantification that characterized traditional ecology.

The first two points concern ecosystem structure (1–2). Holling challenged the idea, common among ecologists, that "everything is connected to everything else" [54] (p. 27). He instead characterized ecosystem structure as a "lumpy" and nested hierarchy where species develop selective relations, forming dense clusters that are tightly coupled within and loosely coupled without [54]. His extended keystone hypothesis then says that "a small set of plant, animal, and abiotic processes structure ecosystems across scales in time and space" [6,65] and that the interplay between certain slow and fast variables is particularly critical for this structure. Slow variables (which change over long time periods) control stability landscapes and determine which regime shifts can occur in response to fast changes. In turn, fast variables can precipitate changes in the set of key slow variables [59,65,66]. Examples are given below.

The other four points (3–6) concern ecosystem dynamics. Holling thought that ecosystems often have multiple equilibria, each with qualitatively distinct dynamics [57]. He advocated a punctuated equilibrium model of change, where dynamics near equilibria are quasi-linear and predictable, and dynamics around equilibrium boundaries and far from equilibria are non-linear and highly uncertain [55,66]. He seems to have distinguished between two kinds of regime shifts. Those triggered by human activity are often abrupt, unexpected, irreversible, and damaging for ecosystems, as illustrated more or less by the pathologies of management [54]. In contrast, natural regime shifts usually respond to natural cycles of variation that are desirable. One reason for this appraisal is that, for Holling, natural variation is often key for ecosystem persistence (see below). In addition, ecosystem collapses release nutrients and niches, and Holling argued that their instability conditions are often opportunistically exploited by novel life forms and processes that can turn out to be beneficial to humans ([54,56,64]).

These ideas are further illustrated with his account of "ecological resilience."

R1: "Measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables" [57] (p. 21).

This definition specifies the outcome (or ex-post aspect) of resilience: in contrast to "engineering resilience", a recovery concept, Holling claims that ecological resilience results in the simple persistence of key populations or species [57] (p. 17); that is why the definition abstracts from return time and, generally, from recovery. Now resilience is, too, a more complex, global, and qualitative property. It does not refer to one stable state defined by quantitative values (e.g., MSY), but to the avoidance of structural shifts between multiple stable states, or to keeping change within limited bounds.

As determinants of resilience (ex-ante aspect), Holling mentions properties like spatio-temporal variability and species richness, especially related to functional redundancy and diversity of responses—see [67–69] for similar accounts. The reason, according to him, is that these properties provide ecosystems with adaptive capacities that are key for persistence and resilience. Note that this means, however, that resilience does not only result in persistence, but also in adaptations, or the ability to adapt. Therefore, if one considers Holling's insights about the determinants of resilience, his 1973 definition (R1) must be modified to preserve the consistency of Holling's view. For example (with changes in italics):

R1′: Measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain *similar* relationships between populations or state variables, *as attained through adaptability.*

In other words, although Holling defines resilience as a rather "conservative" concept, very similar to robustness, when we consider his account of determinants, he really is proposing a more dynamic resilience concept. This account is found, for instance, in three case studies from his 1973 seminal paper, which we revisit next because they clarify a lot about the precise relations between resilience and his other scientific ideas.

One is about rich freshwater systems in the Great Lakes [53] (p. 6ss). Holling explains how, when affected by sustained stress (e.g., through fishing pressure, phosphate loading, etc.), these systems lose resilience slowly until they jump to a degraded state with much less fish stock. Holling takes the example to show that (human-driven) stresses are more dangerous than shocks, since they reduce the amount of disturbance that can flip a system into a degraded state. He adds that such degraded states are hardly reversible and may suffer from hysteresis; even if stressors are greatly reduced or even removed, populations are unlikely to return to their original levels.

Another study is about spruce budworm outbreaks in boreal forests [53] (p. 15ss). Holling shows that budworm outbreaks are episodic, but frantic (a fast variable), and that their predatory activity is decisively mediated by foliage density (medium-scale variable) and crucial for the alternation of spruce, balsam, and fir in the forest (slow variable). The example thus offers a very different account of ecological change, where cross-scale relations and temporal variability enable natural forest renewal and increase resilience.

Finally, a third case shows how the spatial diversity or modularity of Vancouver Island creates opportunities for replacement between caterpillar populations in the case of disasters and bottlenecks [53] (p. 17ss). He stresses how the adaptability of caterpillars developed in part because of these spatial characteristics. The case shows, then, how important biodiversity and spatial diversity are in providing ecosystems with novel and flexible mechanisms that underpin ecosystem renewal and persistence.

In his more theoretical work, then, Holling refers to resilience exclusively as an ecosystem property that captures behaviors neglected in "engineering resilience". As we are about to show, however, he spoke of resilience quite differently in the context of his discussions on environmental management.

3.2.2. Resilience and Environmental Assessment and Management

Most of Holling's proposals for reforming environmental assessment and management are found in his monograph [54], where Holling presents his adaptive method for overcoming the pathologies of management. Table 1 (right) lists ten guidelines and policies he advanced in ecosystem assessment (I–II) and management (III–X) for this purpose.

The assessment prescriptions (I–II) are epistemological and methodological lessons implied in Holling's theoretical insights. Holling disputed the undue ambitions of predictability, a concern we label with the term "punctuated uncertainty". The label is ours, but it captures Holling's insight that scientists can predict dynamics and outcomes near equilibria, but not far from equilibria, where dynamics are uncertain, and scientists need a more qualitative approach to assess them. Holling also complained of data excess and over-quantification, which, in his view, hindered anticipation and responsiveness in management [54] (p. 6). He addressed this problem with the "rule of hand" [54,66]: a method that focusses on a set of three to five critical variables at three different spatio-temporal scales to capture qualitative features of ecosystem complexity, regime shifts, and related uncertainties (following his insights on the extended keystone hypothesis, slow and fast variables, and resilience).

Holling added some general guidelines and specific policies that address the pathologies of management directly (III–X). He said, for instance, that managers can counter instrumentalism by integrating ecological, economic, and social values at the very beginning of interventions [54] (p. 2), and that they can avoid lock-ins and irreversible shifts by remaining flexible and keeping options open [57] (p. 21). He further proposed an opportunistic and experimental approach that avoids "managing too much" [56], and sees crises as sources of learning and opportunity, since endogenizing crises is precisely what creates responsiveness, adaptability, and the ability to benefit from uncertain situations. This latter point relates to Holling's belief that nature itself is opportunistic in unstable situations (see Table 1, point 6) [54] (pp. 205–213).

He also advanced a few specific economic measures, mostly aimed at preventing rebound effects. One was to keep extraction and wastes well below the desired MSY by introducing safety margins to exploitation [70]. Relatedly, Holling advised against subsidizing and overcapitalizing on extractive activities to prevent rebound effects [54,56] (c.f. Section 3). He also claimed that designing with nature is environmentally and economically sound, particularly for saving management costs. For example, he argued that we can turn insect pests to our economic advantage by using them as a "forest manager at places and times where it is not economically feasible for man to do so" [54] (p. 34).

His ideas on the appropriate social embedding of management focus more on avoiding lock-ins and instrumentalism. He recommends tightening feedbacks, although this precise term was coined in later resilience research, e.g., in [68] (p. 139). Tightening feedbacks essentially means localizing knowledge and management to limit the tendency of large-scale projects toward reduced responsiveness. Holling also proposed regions, instead of localities, as the focal management scale, arguing that they are the "obvious" scale where economic and ecological concerns can be monitored and balanced [54] (p. 4ss). He also advocated a decentralized, participatory, and interactive management, involving multi-stakeholder meetings and regular workshops to ensure value inclusiveness [54] (p. 13ss).

Resilience was undoubtedly a key concept among Holling's ideas for reforming ecological assessment and management; the problem is to determine its precise role here. The evidence suggests three possibilities: resilience as an ecological goal for his adaptive assessment and management method; as a general normative vision of the appropriate relationship between humans and nature; and as a label for adaptive management itself.

First, Holling used resilience as an ecological goal. Note that, while the above discussed proposals reconcile Holling's theoretical ideas and his critique of management, they do not include a precise ecological goal. Contrary to efficiency-based and conservationist policy, which are based on one dominant goal (such as e.g., securing stability, increasing efficiency, or strictly limiting social impacts on nature), Holling appealed to participatory schemes for integrating various economic goals from business, social demands from local citizens, and ecological goals from activists and scientists. Holling's ecological goal was presumably that of "building, maintaining and if possible improving resilience", as implied, for instance, by his claim that, to avoid the pathologies of efficiency-based management, management must be "based on resilience" instead [57] (p. 21).

Holling also refers to resilience as a more general vision of virtuous human relationships with nature. Recall that, for Holling, the pathologies of management ultimately resulted from adopting flawed worldviews on nature and human–nature relations. Efficiency-based managers think that nature is "infinitely forgiving" and that "big-is-necessary", two ideas that, taken together, justify the goal of maintaining or upscaling some socially stipulated MSYs. Conservationists, in turn, think that nature is "mischievous" and that "small-is-beautiful", and therefore that human impacts must be strictly limited to keep nature pristine. Holling said that a view of "Resilient Nature" includes the advantages and avoids the problems of these views by demanding an "enhancement of natural systems rather than simply their protection" [54] (p. 33). In this context, he defines resilience as an opportunistic and transformative property:

R2: "[ability] to absorb and utilize (or even benefit from) change" [54] (p. 11).

Finally, Holling uses "resilience" to refer to adaptive management, for example, when he talks about "resilient policies" or "resilient or adaptive policy design criteria" [54] (pp. 2–9). Here, resilience is not a property of ecosystems or a vision of human–nature relations, but a property of virtuous management or organizations, consisting in their:

R3: ability to build or maintain resilience in a target ecosystem.

This concept builds on a metonymy that is fairly common in management and related fields, whereby a cause (for short: organizations or organizational styles) is attributed a quality that primarily pertains to the effects or ends produced by that cause. Planning or control methods are also called efficient or robust, for instance, when they produce efficient or robust results, respectively. In this way, Taylorism is an efficient method of organizing assembly lines, because it prioritizes efficiency and usually leads to efficient production, e.g., more output in less time, at less cost, and/or with lesser use of production factors. In the present case, resilience is used interchangeably with adaptive management, which means that this concept covers or implies the whole set of assessment and policy prescriptions of this method.

4. Discussion

Now we turn to examining how these results challenge the Alliance's orthodox narrative on resilience, and which alternative account emerges in its place. Table 2 collects the uses of resilience identified heretofore, employing categories and concepts introduced in Section 2 for indicating their main sources of variance. The table shows that Holling's uses are all sharply distinct from Pimm's concept ("engineering resilience"), but also that they are hard to reconcile with one another, at least at first glance. As can also be seen, this task is further complicated by the fact that R1′ seems ambiguous between two possible interpretations (highlighted in bold). Building on these preliminary insights, we next raise three problems with the orthodox narrative on resilience, and then articulate our solution to those problems.

Table 2. Typology of uses of resilience in Holling's early work.

Source	Content	Applies to	Concept Type (Ex-Post)	Surrogate Concept	Normativity
Pimm 1984	"Speed of return of variables towards their equilibrium following a perturbation."	(Stable) Ecosystems	Recovery	Efficient recovery (stability)	Instrumental value
R1′ (in text) Holling 1973	Measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain *similar* relationships between populations or state variables, *as attained through adaptability* . . .	Ecosystems	Adaptive **OR** Transformative	Dynamic robustness **OR** Antifragility	Instrumental **OR** Intrinsic value
R2 (in text) Holling 1978	"[Ability] to absorb and utilize (or even benefit from) change."	View of human–nature relations	Transformative	Antifragility	Intrinsic virtue
R3 (in text) Holling 1978	Ability to build or maintain resilience in a target system	Organizations	Transformative	Antifragility	Intrinsic virtue

First, recall that, in the orthodox narrative, resilience originally was a descriptive term. We already argued why this claim was misguided. Now our objection can be further illustrated since all concepts listed here admit descriptive and normative use. Pimm's and R1′ are ecosystems properties, but also instrumental or intrinsic values for guiding ecological design or management—efficiency-based or adaptive, respectively. R2, in turn, is a virtuous ideology or view about human–nature relations, and R3 is a virtue that organizations would want to have, and thus, a goal for organizational design.

The second point is about the kind of system that resilience applies to. R1′, an ecosystem property, is the dominant notion in Holling's more theoretical discussions. Yet, in his work on management, Holling frames resilience as a social property, of "views" or ideologies (R2), or of management and organizations (R3). This point suggests two logically possible interpretive strategies. One is to reconcile these two aspects of Holling's work by framing resilience as a natural and social property. Another is to focus on one of these two aspects, as Brand and Jax do, for example, when they characterize Holling's resilience as a concept of ecosystem science [6]. The problem with this latter approach is that it implies that Holling's work on management is irrelevant and that R2–R3 are spurious.

The third point is similar, but now in relation to the ex-post aspect of resilience. The Alliance is now framing resilience as an adaptive quality that allows systems to maintain functions (and, in some accounts, their structure) through minor changes (cf. Section 2.3). This is an adaptive concept close to dynamic robustness. While Holling's R1′ has often been interpreted along these lines [6], note that this interpretation is inconsistent with R2 and R3, which offer two explicitly transformative notions. In other words, the orthodox narrative implies that Holling used resilience incoherently.

While these difficulties are quite definitive for the Alliance's orthodox narrative, now we are in a position to present an alternative account. Our assumption is that Holling's early work involved the reform of ecosystem science and environmental management, and that a redefined view of resilience was crucial in both of these reforms. In consequence, we argue that these two aspects of Holling's work should be reconciled through a unified account of resilience. We further contend that this can be done by interpreting R1′ as a transformative notion. Let us see how.

To start with, various reasons support this interpretation of R1′. One is its consistency with Holling's early theoretical work. His 1973 case studies (cf. this section), for example, present resilience as a property of specific kinds of ecosystems: diverse ecosystems that display far-from-equilibrium behavior. In various places, Holling attributes such systems with a remarkable ability for generating opportunities for insiders and newcomers, as well as for evolving and reorganizing (see Table 1, point 6) [66]. Those insights then favor an opportunistic and transformative interpretation of resilience, as almost a surrogate of antifragility. Furthermore, this is the only interpretation that renders Holling's work on management intelligible. First, it makes R1′ consistent with R2–R3. Then, Holling conceived of resilience as an ecological goal for fighting the pathologies of management. In a dynamic robustness interpretation, however, R1′ means something similar to lock-in, and it can be an instrumental or an intrinsic value, depending on the perception (cf. Section 2.2). Antifragility, instead, is an intrinsic value that implies a potential to escape lock-ins and to use change to one's benefit. This latter view clearly is more conceptually fit for fighting the pathologies of lock-ins and instrumentalism.

Now consider the concept that emerges. From an ex-post perspective, R1′ and R2–R3 are now aligned in that they present resilience as a transformative notion, whereby resilient systems can persist and adapt, but also utilize change to reorganize, transform, or improve. Resilience is also a strongly and explicitly normative notion, which guides action in three areas simultaneously: first, as an intrinsic ecological goal for designing and reforming ecosystems (R1′); second, as a goal for designing and reforming management styles and organizations (R3); and finally, these two ideas imply a third one, whereby resilience is an appropriate view of the relations that humans should have with nature (R2).

One important consequence is that, thus viewed, resilience is not a mere property of ecosystems, but a property of socio-natural ensembles. Such a result should not be surprising, considering that Holling's early work on resilience later motivated and underpinned the stream of social and ecological research that became the central business of the Resilience Alliance. This idea is manifest in the fact that the determinants of resilience are natural or ecological (i.e., the ecosystem features mentioned in this section) as well as social (i.e., the guidelines of adaptive management entailed in R3).

Table 3 summarizes these points, including a proposed redefinition of resilience that aspires to integrate the main aspects of R1′, R2, and R3.

Table 3. Unified account of Holling's early resilience.

Resilience Definition	Ex-Post Aspect	Ex-Ante Aspect	
		Ecological Determinants	**Social Determinants**
Ability of management and societies to maintain and utilize the capacity of ecosystems to absorb change and still maintain similar functions, and to exploit instability for adapting or evolving	Persistence Adaptability Opportunism (ability to evolve and improve through instability)	Temporal variability Spatial diversity (mosaics) Functional redundancy Diversity of responses	Punctuated uncertainty (assessment) The rule of hand (assessment) Integrates values Flexible organization, avoids irreversibility Opportunistic, experimental approach Safety margins, avoid subsidies Designs with nature Tightens feedbacks (localizes power/knowledge) Regional scale of management Decentralized and participatory

As a final comment, these results also take us very far from the view that it was the recent social work on resilience that undermined the precise and scientific character of this term (cf. Section 2) [6]. In his early work, Holling used resilience as a rich and multi-disciplinary concept that, besides its technical content, had three normative functions:

as an intrinsic ecological value, as a virtue of organizations or management styles, and as a virtuous understanding of human–nature relations. However, his characterization was not only inherently complex, but also quite often vague or ambiguous. Thus, the persistent difficulties around the interpretation and use of resilience are not the sole responsibility of social scholars or resilience practitioners; many of them can be traced back to Holling's original work on the concept. The good news is that our proposed account of Holling's resilience eliminates most of these difficulties.

5. Conclusions

Our proposed account of resilience has several advantages. Here, we mention some by way of reflecting over the results of our analysis.

First, this account stresses the relevance of Holling's original work for much of the current resilience research and resilience-building efforts. Discounting possible posterior revisions of this concept by Holling himself or by his colleagues at the Resilience Alliance, we have shown that Holling first conceived of resilience as an approach for transforming and opportunistically improving ecosystems and the social organizations that design or control them. This is basically how resilience is understood today in many fields and practices, notably in the context of adaptation. The *100 Resilient Cities* program, for example, uses resilience as a notion for transforming cities, their infrastructure, and their governance systems, as well as for thinking differently about the urban governance nexus in the context of ecological disruption [1]. It has been similarly noted that resilience approaches to adaptation inherently concern reforms in hard infrastructure or community resources, as well as in soft infrastructure or policy frameworks [22]. In addition, the *Intergovernmental Panel on Climate Change* advocates for a transformative view of adaptation, whereby climate change mitigation is the first adaptation duty, and adaptation should ideally be opportunistic [71]. These ideas all resonate with our interpretation of Holling's resilience, which partly explains the success of resilience in adaptation and related fields.

This paper has also helped to reposition resilience vis-à-vis some competing and closely overlapping concepts. Despite the clear links between resilience and various robustness and stability concepts, we find resilience more closely related to antifragility, a concept that describes opportunistic transformation in the face of change. Holling's resilience differs from antifragility, however, in one subtle respect: its explicit dual character. Resilience is a social transformative property, but one that decisively rests on taking action to preserve or improve a similar transformative capacity in ecosystems.

This dual character of resilience sheds new light particularly on the relations between resilience and sustainability. Unlike other conceptualizations of resilience, Holling's resilience addresses the double dimension of sustainability (cf. Section 2), since it is a goal for securing ecological features that are viewed as the preconditions for attaining certain socially valuable goals. In fact, many of Holling's critiques and proposals make sense within the context of a progressive approach to sustainable development. Today, Holling would rightly dispute the efficiency basis and the technological and technocratic orientation of ecological modernization discourses, such as [72,73]. However, he was also possibly right in dismissing certain obsessions with ecological limits, both on scientific grounds (consider his rejection of MSY, or more generally of the idea of a fixed carrying capacity) [57,74] and because of the negativity and paralysis such discourses may induce on social action [54,56]. As Holling himself insisted [54,75], these features of resilience bring it close to the idea of sustainable transition, at least closer than is usually recognized [14,15], and insofar as we are talking of social and ecological resilience specifically. There are, however, two crucial points to be made here. One is that resilience is being applied today in many ways that no longer retain this link with ecological conservation and sustainability [14,15]. Another is that the normative basis of resilience is much less explicit and convincing than that of sustainability. This takes us to our last point.

This paper has drawn attention to morally relevant aspects of resilience that are neglected in what we called the Alliance's "orthodox narrative" on resilience. Looking at resilience as a descriptive term is a mistake that can raise several further confusions, such as there being no normative decisions to be made in resilience practice. Not only is this idea misguided, it can moreover carry the profound danger of depoliticization, which has been rightly criticized by resilience scholars [11,12,76–78]. Trying to avoid this problem, in this paper, we stressed the normative aspects of Holling's critiques and proposals. We have shown that Holling's ideas parallel normative arguments that, in the 1970s and later, have been popular in various domains, especially as they converge around the rejection of efficiency and stability as suitable values for planning and design [29,79], or around concerns for over-quantification, optimization, and utilitarianism (here viewed as the short-run maximization of welfare) in risk management and related areas [80–83]. In addition, we selected a battery of explicit and concrete "resilience-based" measures that can be of much utility in prompting further debate over the normative concerns that resilience approaches do or do not capture, at least currently. For example, social and social/ecological resilience inevitably advances some notion of justice between generations, or intergenerational justice. Likewise, procedural justice is partly attended through social determinants of resilience, such as "integrating values" or promoting "participatory management". In contrast, resilience seems to care little about distributive justice, that is, about addressing present inequalities or disadvantages. This point resonates with the popular concern that resilience is not a pro-poor concept [8,84], and it casts doubts on the potential of resilience as a sustainable development or a climate adaptation narrative. In addition, Holling's approach has other problematic aspects, such as the potentially unfair and unjust consequences of applying an "experimental" attitude to social contexts [85]. These and other morally sensitive issues around resilience deserve more attention than they have received to date [10,86].

We conclude with two caveats about the limitations of this study and the needs for further research. First, we have proposed a philosophical characterization of resilience that attends to the following aspects of this concept: what resilience is as a response to disturbance (ex-post aspect); what are its determinants (ex-ante aspect); how resilience stands in comparison with closely related concepts; and how to characterize its normative profile. Our account therefore impinges on points that are key to address in framing resilience for resilience-based interventions, but it also leaves out many critical decisions that belong to later stages of these interventions; examples abound. One is how to choose indicators of resilience and what are the problems involved, for instance, in normalization, aggregation, or in comparing the resilience of complex systems that differ in many dimensions, such as cities [86]. Also in need of further research is the question of how our characterization of resilience could inform the development and prioritization of concrete resilience-based strategies and policy, be it at a corporate, city, or country level [87].

Second, we want to stress that this article did not intend to offer a definitive and universal account of resilience, but only a minimal account that aptly addresses certain misunderstandings. While we defined resilience as an opportunistic transformation of some complex system and of the organizations that manage it, for example (see Table 3), our definition leaves it unspecified which are the goals of transformation or the desired circumstances and means for opportunism. This result may disappoint those scholars and practitioners who strive for a resilience blueprint that is applicable across all systems and circumstances. However, it also means, for example, that crucial decisions about resilience planning and management, even at the level of framing resilience, can still be made through participatory schemes. This demand is common among resilience scholars [88] and, as we saw, can also be attributed to Holling himself.

Furthermore, our account builds directly on Holling's early ecological and social/ecological research to propose an alternative to what we called the Resilience Alliance's "orthodox narrative." Holling's and the Alliance's works on resilience are influential and relevant enough to warrant the applicability of our conclusions to many other streams of resilience research. Yet, one must be careful about generalizing to areas such as safety engineering, where resilience has made much fortune [35,87,89]. In our view, Holling's resilience is an ability that societies have for opportunistically exploiting the capacity of ecosystems for evolving and transforming themselves. In contrast, engineering systems like infrastructures lack a capacity for self-organization and evolution, and indeed, these systems are often described in terms of their inertia, obduracy, and lock-ins [46,47]. This means that, in engineering fields, a socio-technical approach is indispensable for underpinning the flexible and transformative behavior that seems inherent to resilience, and we still may not be talking of resilience as the same kind of property in both contexts. This key difference has been noted by transition scholars [15], and it demands further research on how to exploit resilience thinking coming from ecology.

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