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COMMENT

Comment on 'In complexity we trust: learning from the socialist calculation debate for ecosystem management'

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Abstract

Using a metaphor based on a historical debate between socialist and free-market economists, Salliou and Stritih (*Environ. Res. Lett.* **18** 151001) advocate for decentralizing environmental management to harness emergent complexity and promote ecosystem health. Concerningly, however, their account seems to leave little room for top-down processes like government-led sustainability programs or centrally-planned conservation initiatives, the cornerstone of the post-2020 biodiversity framework. While we appreciate their call for humbleness, we offer a few words in defense of planning. Drawing on evidence from ecology, economics, and systems theory, we argue that (1) more complexity is not always better; (2) even if it were, mimicking minimally-regulated markets is probably not the best way to get it; and (3) sophisticated decision support tools can support humble planning under uncertainty. We sketch a re-interpretation of the socialist calculation debate that highlights the role of synthesis and theoretical pluralism. Rather than abandoning big-picture thinking, scientists must continue the difficult work of strengthening connections between and across multiple social, ecological, and policy scales.

1. Introduction

If we want to make ecosystems better, how should we conceptualize the role of the manager? In their recent article (henceforth 'the Perspective'), Salliou and Stritih [1] consider (socio-)ecological systems better when they are less fragile, more efficient, and more productive. Using the socialist calculation debate as a metaphor [2, 3], they advocate for a highly localized, hands-off approach to ecosystem management, trusting the combined effect of many independent choices to generate something like the spontaneous order described by the free-market economist Friedrich Hayek. The metaphor suggests that scientists should redirect their energy away from 'large-scale top-down solutions' to the global sustainability crisis, and focus instead on small-scale processes (p 3). This argument hinges on three propositions: (1) economies and ecosystems are better when they are more complex; (2) complexity cannot be effectively designed, but emerges organically from the aggregation of many independent interactions; and (3) because planning processes are uncertainty-averse, they make systems simpler and therefore worse.

But there is a problem: none of these propositions is quite true. We highlight evidence from ecology, economics, and systems theory indicating that the most complex systems are not necessarily more stable or productive, but can be inefficient and exceptionally fragile. Next, we point out that ignoring the big picture risks generating an ecologically impoverished 'emergent simplicity' in which agents all converge to the same solution. Instead, we suggest uncertainty-integrating techniques from decision science that can support resilience and adaptiveness. Finally, we outline an alternate reading of the calculation debate that emphasizes complementarities between top-down planning and emergent complexity. Scientists must continue the difficult work of strengthening connections across multiple social, ecological, and policy scales.

2. More complexity is not always better

While the era of central planning in Eastern Europe coincided with major advances in economics as scholars grappled with allocation problems in complex dynamic systems [4], its final decades also saw another discipline embroiled in a battle with complexity: ecology. Drawing on findings on the behavior of highly connected systems with gross feedbacks, Robert May [5] famously demonstrated that increasing species diversity could *de*-stabilize some ecosystems. His work sparked a debate [6] about the ecological implications of complexity that remains among the most challenging open issues in our field [7, 8]. Is there a point beyond which increasing complexity can generate not only diminishing, but strongly negative, returns in terms of ecosystem health? If so, what determines this upper bound?

Today, we know that complexity can confer many benefits to ecological communities—but it is not a panacea, either. Its influence on different dimensions of ecosystem health is uneven and context-dependent [9], varying in strength and sign [10, 11] and exhibiting non-linearities across scales [12, 13], including species richness-ecosystem functioning curves that saturate at just a handful of species [14, 15]. Interaction types and network structures vary, and even when they are robust to past disturbances, complex ecological networks can become suddenly fragile when confronted with new threats [8, 16, 17] or destabilize as they disperse across space [7]. And because the effects of introductions cascade through interaction networks, it is often difficult to predict whether they will reinforce or undermine the integrity of a given ecosystem [11, 18, 19]. Thus, attempting to artificially increase complexity can have unintended consequences [13, 20, 21] and entail trade-offs with other desirable system features, like resilience, robustness, or productivity [16, 22–24].

Grassland ecology offers notable empirical examples [25, 26]. Twenty years ago, a widely-cited experiment showed that species-poor grasslands can be more resistant and resilient to drought than species-rich ones [27]—a finding with fresh, if partial, support from Craven *et al* [28]. More recently, a large-scale study showed that increases in species richness were not only associated with, but actually caused, declines in grassland productivity [29]. The notion that increasing complexity enhances ecosystem health is generally, but not universally, true [30].

The economic implications of ecological complexity are also uncertain [31]. Evidence regarding the impact of biodiversity on crop yield and carbon storage is mixed, and higher biodiversity sometimes reduces the provision of certain ecosystem services [32, 33]. In biocontrol, for instance, more diverse natural enemy communities can be less effective due to intraguild predation and behavioral interference [34, 35]. More generally, the cascade-mediated relationship between biodiversity and economic value exhibits functional forms ranging from positive-convex to negative-concave [36], which has important implications for coupled human-natural systems.

3. Emergent simplicity as a risk of decentralization

The Perspective proposes one simple rule for generating complexity: subsidiarity. It contends that devolving decisions to the smallest possible scale would empower 'individual ecosystem managers' to customize management, generating a diverse tapestry of human-nature interactions collectively superior to any top-down solution. Indeed, local communities sometimes do self-organize to sustainably manage common-pool resources, although consensus about essential considerations like scale limits [37], necessary and sufficient conditions [38], and the role of nestedness [39] has proved elusive.

While we agree that leaving leeway for adjustment is important, decentralization is not the whole answer—or even a new one. In reality, landscape mosaics consisting of many small, independently-managed ecosystems are often remarkably homogeneous [40, 41], simply because their 'ecosystem managers' are typically private owners like farmers or foresters, who can be conservative in their practices [42], disposed to reactive planning [43], and reluctant to cooperate to overcome collective action problems [44]. Inducing them to deviate from 'tried-and-true' (but unsustainable) practices often requires both technical support and financial incentives [45, 46], typically by way of government programs guided by publicly-funded research.

Consider eucalyptus plantations in Portugal [47], even-aged spruce monocultures in Germany [48], livestock-driven deforestation in Brazil [49], or grasslands converted to family-owned corn and soy farms in the US Midwest [50, 51]. Such ecological homogeneity is rarely planned explicitly from the top down. Instead, it represents a kind of 'emergent simplicity' wherein agents with similar knowledge and capabilities all encounter the same incentive structure and predictably arrive at the same result. Even if that result were to support biodiversity within each management unit (α-diversity), replicating it across the landscape can still generate uniformity along other dimensions or scales (e.g. low β- or γ-diversity) [7, 52].

4. Coordination across scales

In holding up free markets as an example for ecosystem management, the Perspective fails to recognize that markets literally—not metaphorically—determine how a large proportion of the terrestrial surface is being managed right now [53–56]. Recently, for instance, one of us showed that national-scale deforestation trends in countries as diverse as Brazil, Indonesia, and the Democratic Republic of the Congo can be reproduced by simulating millions of individual choices by heterogeneous agents making satisficing decisions in response to market signals [57]. Despite its admission that 'self-organizing markets' are often 'ill-suited' to provide public goods (p. 2), the Perspective puzzlingly skips over the fact that the pervasiveness of public goods problems and transboundary processes has long been one of the defining challenges of environmental management. What does it mean to prescribe subsidiarity as an organizing principle for a set of problems—climate change, ocean acidification, telecoupled deforestation—where 'the smallest possible scale' is so often undefined?

Even if we dedicate ourselves to conjuring emergent complexity by abandoning the big picture for the small scale, there is little reason to think that more predatory interests would do the same. When state power recedes in the name of decentralization, major beneficiaries often include local elites and well-financed outsiders, who can find community-level decisions easier to co-opt or subvert than governmental ones [58]. For the same reason that large corporations seek to shape public policy through lobbying, they have also been known to bring asymmetric power to bear on local decision processes, whether to gain license to engage in damaging activities [59, 60], or to protect natural resources from collective degradation by economically-competing smallholders [45].

Our point here is not that bottom-up processes are without merit—only that they cannot be the whole answer. We share the Perspective's concern that the growing popularity of large-scale modeling work powered by vast datasets sometimes produces results that are difficult to reconcile with realities on the ground, and that overreliance on such a birds-eye view could potentially contribute to heavy-handed policy interventions that ride roughshod over the diverse needs of local communities [61, 62]. But the relationship between macro research and bottom-up processes is not always antagonistic: effective, progressive municipal-level climate action is often spurred by, and capitalizes on, global issue framings that owe their credibility and salience to birds-eye scholarship [63, 64]. The uncomfortable truth is that different kinds of environmental problems require action at different scales, posing often-messy [64] multilevel, polycentric coordination problems that—despite their many challenges and uncertainties—cannot be made to vanish simply by ignoring them and declining to coordinate at all [65].

At the policy level, we think biodiversity tends to flourish when public bodies intervene to disrupt the emergent simplicity of market-driven homogenization, including through centrally-planned interventions like environmental regulations and energy policies [66], economic incentives to adopt best management practices [67, 68], and diplomatic accords like conservation action plans to support *in, inter,* and *ex situ* genetic repositories [69–71]. At the management level, we agree that the Perspective's favored 'hands-off' restoration strategies (e.g. trophic rewilding, restoring connectivity, etc) are probably underused—but stress that they can involve major interventions [72] and entail trade-offs that may not be visible at small scales. Removing a hydroelectric dam might mean trading global benefits, like reduced carbon emissions, for local ones, like freshwater biodiversity [73, 74]; promoting connectivity in fragmented landscapes can sometimes reduce resilience or the provisioning of ecosystem services [52, 75, 76]. In such cases, planning and coordination across geographic and policy scales are needed.

5. Planning under uncertainty

Environmental management in the Anthropocene demands humility: *inter alia,* leaving margins for error, supporting the capacity of systems to adapt and re-organize, and accommodating local socioeconomic and ecological realities. The Perspective suggests that this problem is too complex to solve, so attempting to chart a top-down course of action based on crude projections can only make things worse. But if complexity must be promoted selectively and decentralization is not a silver bullet, then we must decide when, where, and how to intervene—that is, to plan.

Fortunately, the tools available to ecosystem managers today are more sophisticated than either Gosplan-style material-balance planning or the sprawling linear programming models used to centralize forest planning in the US well into the 1980s [77]. Today's tools can also be more humble, as decision science continues to innovate adaptive, uncertainty-integrating techniques. Incidentally, some of these tools actually did originate in the kind of loosely-regulated financial markets that fascinated Hayek—just not as avatars of stability-through-complexity. Instead, they were attempts to grapple with the volatility that often accompanies deregulation.

Modern portfolio theory, for instance, uses information about correlations between fluctuating asset values to optimize multi-asset investment decisions under risk [78]. Stochastic programming, a probabilistic technique, aims to balance performance under expected conditions against the need to preserve the future action space in case of unlikely events; some versions can reveal, in advance, the optimal response should such an event occur [79]. Bayesian methods, such as belief networks with updating, use similar probabilities to descriptively model complex systems, including decision-makers [80] and the dynamics of their behaviors over time [81]. If quantitative information is lacking, knowledge-based fuzzy logic networks can support decision-making under uncertainty [82]. And when planners face deep uncertainty—meaning that potential futures can be identified but not ranked by likelihood—robust optimization can be used identify the best result that can be achieved even in a perfect storm of worst-case conditions or unexpected shifts in social values [83]. These techniques all have growing track records as more humble ecosystem management tools. Appropriately applied, they can help buffer social, economic, and ecological uncertainties [84, 85].

6. A new metaphor for ecosystem management

So far, we have argued that (1) more complexity is not always better, (2) even if it were, mimicking minimally-regulated markets is probably not the best way get it, and (3) sophisticated decision tools can support humble planning under uncertainty. What does this mean for the socialist calculation debate as a metaphor for ecosystem management?

We think it still offers useful lessons, but a few historical and theoretical clarifications are in order. First, we should abandon the idea that the dissolution of the USSR—an idiosyncratic historical event that unfolded under an immensely complex constellation of sociocultural, economic, and geopolitical circumstances—is attributable to, or offers definitive conclusions for, an academic debate about the theoretical (im)possibility of rational economic planning [86, 87]. Many economists considered the debate closed before the Cold War even began; the premise that the Austrians were proved 'right' is controversial among economic historians; both the Marxian and Austrian schools made major concessions; and both are now considered heterodox [2, 3, 86].

Today, mainstream macroeconomics rests on a framework called the new neoclassical synthesis (NNS), which views market competition as powerful but imperfect tool. Market failures are common, for instance, in contexts featuring non-rivalry, non-excludability, externalities, or asymmetric information [88, 89]. The NNS also emphasizes the volatility of complex systems, which are subject to cyclical fluctuations, real shocks, and contagion [90, 91]. Thus, rather than relegating central authorities to passively providing boundary conditions and enforcing property rights, it assigns them a more active role that includes directly intervening in markets to stabilize them [92]. In behavioral and applied economics, theory is even more pluralistic, embracing constructs like optimization, game theory, and 'designed' markets like auctions, while moving beyond rational-actor models to explore how cognitive factors shape economic behavior [93–95]. In short, modern economics is much more than a series of tributes extolling the virtues of deregulation and decentralization; it is a colorful, dynamic discipline deeply interested in how planning and design can structure interactions between agents to enhance social welfare.

The socialist calculation debate, then, should not be read as a Darwinian parable in which one school vanquishes another in a zero-sum game. Instead, its legacy is integration: paradigms that initially appear in diametric opposition are gradually made commensurate through a process of exchange, mutual adjustment, and synthesis, until their core insights are finally assimilated to reinforce a larger and more powerful framework.

And as for economists, so for ecosystem managers: for better or worse, we have to negotiate a shifting balance between top-down and bottom-up processes that often seem to resist one another. Small-scale dynamics and participatory frameworks will continue to play an indispensable role; we should strive to strengthen and accommodate them. But the suggestion that planning and coordination can only make things worse runs contrary to large bodies of scholarship, as well as the scientific consensus on the urgent need for coordinated international action to combat climate change and biodiversity loss [71, 96].

7. Conclusion

Centrally-planned conservation initiatives form the cornerstone of the post-2020 biodiversity framework [97]. We believe that such initiatives need more support, not less. We are concerned that the Perspective's well-intentioned call for humbleness could instead be interpreted as an argument to do nothing.

In glossing over gray areas in economic history, its metaphor fails to capture the delicate balance that ecosystem management must strike between local and global, mitigation and adaptation, and different components of complexity and ecosystem health. It represents economics and ecology as separate realms, obscuring the reality that they are not only inextricably entwined, but also that this entwinement lies, observably and concretely, at the heart of the global sustainability crisis. The troubling (we think unintended) implication seems to be that we are so utterly helpless against the scale of that crisis that it would be better to give up on charting a course at all: instead of working on 'large-scale top-down solutions', we should each choose our own path and hope it all works out in the end. Cynical actors [96] might find this reading appealing and cite it to undermine government-led sustainability initiatives or to scientifically legitimize dangerous arguments for deregulation and the privatization of nature.

We hope that our comment can offer a countervailing view. In a telecoupled world facing accelerating anthropogenic disturbance, promoting devolution based on *laissez-faire* capitalism is inadequate to safeguard the environment. So in keeping with the legacy of the calculation debate—and, we think, the larger spirit of the Perspective—we call for embracing synthesis, heterogeneity, and theoretical pluralism, from the top down and from the bottom up. Rather than abandon the big picture, we must continue the difficult work of strengthening connections across scales while investing in tools that can enable us to plan humbly, foster adaptive decisions, and leave space for self-organization—just without placing too much faith in the invisible hand of a fickle emergent complexity.

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