

Letter to the Editor

Response to: Comment on “Resilience of Complex Systems: State of the Art and Directions for Future Research”

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Lade and Peterson [1], L&P hereafter, recently commented on our article by Fraccascia, Giannoccaro, and Albino [2], FGA hereafter, which provides a systematic literature review of the resilience of complex systems covering various disciplines, including environmental science, ecology, operation research, management science, engineering, computer science, economics, and psychology.

L&P’s concern regards the search terms used by FGA in the literature review (“resilience” AND “complex system*”), which in their opinion are too narrow and limit the search results. They argue that additional search terms should have been considered, in particular: (1) synonyms of complex systems, such as ecosystems, socio-ecological systems, communities, and organizations; (2) subtypes of “complex systems,” such as complex adaptive systems; and (3) synonyms of “resilience” such as robustness and vulnerability.

We respectfully disagree with L&P for the following reasons. First, as noted by L&P themselves, the novelty of FGA’s literature review is the “[...] *focus on specifically the resilience of complex systems. For such a review, not all literatures on resilience may be relevant.*” Consistently, FGA chose to limit the literature analysis only to articles explicitly referring to both resilience and complex systems. Introducing synonyms of resilience would have required a clear and well-established classification of all resilience dimensions across fields for complex systems, which is currently lacking [3]. Thus, we believe that the use of the search term “resilience” avoided any bias resulting from the choice of resilience dimensions to

include. This approach is consistent with search terms used in previous literature reviews by Xu and Kajikawa [4], Baggio, Brown, and Hellebrandt [3], Annarelli and Nonino [5], Righi, Saurin, and Wachs [6], and Kamalahmadi and Parast [7] (see Table 1).

We disagree also with L&P’s argument to use the search terms “ecosystems,” “social-ecological systems,” “communities,” and “organizations” because they are synonyms of complex systems. In our opinion, rather than being synonyms, they are properly examples of complex systems. Example is different from synonymous. In fact, for instance, not all organizations or communities are examples of complex systems. Hierarchical and autocratic organizational structures working in static environments do not exhibit complex system properties.

Even though we disagree with L&P’s motivation, we recognize that FGA could have used examples of complex systems as search terms. However, this would have required us to preliminarily classify all examples of complex systems. In fact, not only ecosystems, communities, or organizations, as suggested by L&P, but also other systems, such as teams [8, 9], industrial clusters [10], supply chains [11, 12], and economic systems [13, 14], just to name a few, have been shown to exhibit complex systems properties. Therefore, FGA would have included a long list of complex system examples, in order to properly follow this search direction, with the risk, in any case, of not being exhaustive. Privileging some examples (e.g., socio-ecological systems or ecosystems) with

TABLE 1: Search terms used in previous literature review analyses.

Papers	Search terms
Xu and Kajikawa [4]	“Resilience” in the topic
Baggio, Brown, and Hellebrandt [3]	“Resilience” in title
Annarelli and Nonino [5]	“Resilience” or “Resilient” in title and abstract
Righi, Saurin, and Wachs [6]	“Resilience engineering”
Kamalahmadi and Parast [7]	“Supply chain resilience,” “resilient supply chain,” “enterprise resilience,” “organization resilience,” and “resiliency in supply chain”

respect to others (e.g., supply chains or teams) would have also included a bias in the literature analysis. Therefore, we believe that not using any example of complex system as search term was a right approach.

L&P also suggest using subtypes of complex systems as search terms, such as “complex adaptive system.” In line with the reasoning above, this choice would have required us to consider all the subtypes of complex systems. Focusing on complex adaptive systems would have limited the search only to this class of complex system, neglecting others. While this class is quite popular in ecological and ecosystems literature, it is less applied, for example, to study individuals, groups, and organizations, where Ising-based spin models are more commonly adopted [14–17]. Using only the search term “complex adaptive systems,” as proposed by L&P, would have fit the environmental science and ecology research area, but it would have been not consistent with the other research areas. Therefore, we believe that FGA’s approach to use the general term “complex system” guaranteed consistency across research areas and avoided biases due to partial preliminary knowledge concerning the subtype of complex systems used in various fields. Nevertheless, we recognize that this choice could have limited the search results in some research fields more than others. However, we disagree with the conclusion made by L&P that FGA’s review “*was likely biased towards technical and business fields and underrepresented research on the resilience of complex human systems.*” As said above, complex adaptive system framework is popular also in management studies [9, 11–13], so that we believe that this area was not overestimated compared to the others.

Furthermore, we note that it is not surprising that, extending the search terms to “resilience” AND ((complex NEAR/2 system) OR “social-ecological system” OR “community” OR “organization” OR ecosystem), the number of articles selected differs, especially for the environmental science and ecology subject areas, as shown by L&P. We believe that the real value of a literature review is much more than simply the number of articles or which ones are in the top five positions. It should provide a comprehensive and reasoned analysis of a topic, useful for its recognition and development. In our literature review, FGA identified the main authors and research groups as well as the complex systems analyzed in each field, the types of disturbance affecting the system, the main dimensions of resilience, and the main attributes of the system affecting resilience. We believe that “*complicated*

(*and iteratively developed*) search terms even common when conducting systematic literature reviews” are justified only if they are really required on the basis of a cost-benefit analysis. In this, perhaps, we disclose our management and business-oriented background much more than for what was argued by L&P. The cost-benefit analysis suggests investing in “complicated” search terms only if the findings achieved with limited complicatedness should be erroneous or different. This is not the case of the study by FGA. Consistent with Xu and Kajikawa [4] and Baggio, Brown, and Hellebrandt [3], FGA find that there is a limited unified understanding of resilience across disciplines, since some dimensions of resilience (recovery and adaptive capacity), as well as some attributes of the systems (redundancy and connectivity), are shared by a number of research areas. This confirms the interdisciplinarity of resilience research [4] and that resilience can be considered a boundary object [3]. FGA also find that citations are concentrated within each research area, with a limited number of cross-field citations. This confirms a previous result by Baggio, Brown, and Hellebrandt [3]. As to FGA’s sample, even though in the FGA’s analysis Carl Folke and Brian Walker do not result as the first and second most productive authors, they are however identified as key authors (as noted by L&P). Furthermore, even though the study by Elmqvist et al. [18] is missing from FGA’s sample, the importance of diversity as a driver for ecosystem resilience has been properly recognized. Based on the above, we believe that FGA’s study provides an accurate understanding of the current state of the art on resilience of complex systems and also contributes to the literature by highlighting new gaps and further research directions.

Finally, we kindly thank Lane and Peterson for the interest in FGA’s work and for sustaining our call for increasing collaboration across research groups and disciplines. This would also contribute to sharing a common vocabulary that would facilitate multidisciplinary literature analyses, communications between researchers from different fields, and, in the end, the integration of knowledge coming from different expertise and domains, required for generalizing resilience of complex systems.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

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