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Invited reply

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We agree with Larkin *et al*. 2019: restoration is context specific

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We welcome the opportunity to further discuss our analysis and conclusions [1] that Larkin *et al*.'s [2] (hereafter LEA) comment provides. In this response, we first discuss mischaracterizations and criticisms of our analyses, then highlight how the main conclusions from both LEA's and our analyses are similar, and end with further discussion of what both analyses suggest for restoration and conservation moving forward.

LEA contend that the response ratio is 'fundamentally flawed'; given its prominence in the restoration [3–5] and meta-analysis literatures [6–8], we suggest that the matter of its usefulness or lack thereof is far from settled and leave it to meta-analysis statisticians to discuss its utility. For those interested, both LEA and we consulted with meta-analysis statisticians who came to different conclusions (see published reviews of LEA's comment). We further direct readers to the reviews of LEA's comment for a more in-depth response to their criticisms on the choice of variables to calculate response ratios, of how to treat response ratios that overshoot recovery goals, exclusion of invasive species disturbances, and of minimal sample size calculations.

We appreciate LEA's point that data analyses are sensitive to outliers, and this is particularly true in meta-analysis. The reason for removing outliers from a dataset is that they exert undue influence on the statistical analysis. In our analysis, the data were almost always removed as outliers for the resilience metric because the authors had measured recovery over a period of hours or days, which highly inflated recovery rates. Thus, we do not find it surprising that when LEA included outliers, their results differed slightly from ours. We contend that leaving these inflated recovery rates in the analysis highlights differences that are a result of mathematical anomalies (rates being higher because of a very small denominator) rather than biological realities. We appreciate LEA catching the error we made in the outlier removal process, which resulted in us excluding three papers that should have been included. We ran the models again with the correct outliers removed and it did not change our conclusions.

LEA used a completely different statistical methodology to analyse less than half of our original dataset; they only included studies that had two time points of data after the disturbance was removed. Generalized estimating equations, unlike our methods, are not likelihood based and they are semiparametric (meaning they have some non-parametric components). So, the LEA analysis has different assumptions and approaches than our analysis. We find it striking that despite the different approach, LEA's results are remarkably similar to our own (see fig. 3 in [1] and electronic supplementary material, fig. 1 in [2]). But, because the statistical approaches are different and because of the inclusion of outliers, their approach gives some *p*-values stating significant differences, despite substantial overlap of nearly all confidence intervals.

We agree with a number of the points made by LEA. Defining passive versus active restoration is particularly difficult and confounding, which LEA highlight, has been reviewed in the literature [9–11], and we extensively discussed in our original paper. It would be useful if restoration ecologists could come to a consensus on a specific way to categorize the difference. However, the debate persists because it is so difficult to do so as restoration actions exist along a continuum. We debated heavily among authors the definitions we would use and analysed data using a variety of definitions. When we changed various categories of restoration types to passive or active (e.g. changing reconnecting hydrology to active), we still found no differences between the two categories.

Despite having contributed to the ongoing debate about this definition, we wonder if that debate detracts from a potentially more important point, namely that short-term restoration approaches cannot and should not replace conservation or long-term investment in ecosystem restoration. Conservation of relatively undisturbed habitat will continue to be critical, given the restoration debt recovering ecosystems face [12] and how little full recovery ecosystems have achieved [1]. As LEA point out, there is considerable focus on the short-term benefits of low-cost projects, and well-publicized and ambitious targets for the amount of area to be restored, such as the Aichi target of restoring 15% of degraded ecosystems. Focusing on the area committed to restoration over the short term comes at the expense of pursuing restoration that achieves improved biodiversity and ecosystem services over the long term [13].

We highlight that in spite of differing opinions regarding statistical approaches, LEA's major conclusions are consistent with ours. Meta-analysis allows us to glean generalities from many studies across the globe on a particular topic. Such coarse resolution is difficult then to apply to on-the-ground projects, a point we emphasized in our original paper, and LEA repeated in theirs. As we both stated, restoration projects are context-specific, and restoration strategies should be tailored to overcome specific barriers in individual sites, taking into account local ecological and socioeconomic conditions.

Moving forward, both LEA and our analyses point to the need to continue evaluating what is working in restoration, what is not, and where the largest potential for sustained, large-scale, and cost-effective restoration gains exist. The United Nations recently declared the next decade the 'Decade of Ecosystem Restoration'. If we are to get restoring ecosystems right in the next decade, then it is critical that we identify where active restoration efforts are most needed, where ecosystems themselves are resilient and only need to be unencumbered by further disturbance, and where we need to conserve ecosystems because they are unlikely to recover with or without active restoration. Our analysis was a first global inquiry into these questions, but we agree with LEA that looking deeper is required. We encourage future studies that drill down into specific disturbances, ecosystems, and socio-political contexts to further illuminate how and where we can maximize the benefits of restoration.

Data accessibility. This article has no additional data.

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Competing interests. We declare we have no competing interests.

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