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RE-NEW OPINION ARTICLE

Aspirational goals for the future of functional traits in restoration: a response to Gornish et al. (2023)

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Quantitative functional traits, as presented in the ecology literature, can add great utility to the restoration toolbox. Yet, we see significant barriers to the realization of this utility in restoration practice. By addressing these barriers through co-producing research, developing tools, and modifying policy, the field of restoration ecology can greatly increase the utility of traits. Gornish et al. (2023) argue that functional traits are already widely used in restoration projects and challenge the logistical feasibility of some of our proposed solutions to promote the use of traits in restoration. Here we continue the conversation and expand on our vision for the future of functional traits in restoration. We contend that we should not be content with the current state of the field and show how focus, inclusion, and ambition can drive advancement.

Key words: plant functional traits, trait-based restoration, visions for the future

Implications for Practice

- Targeted research to tackle barriers to functional trait usage can lead to more successful restoration projects.
- By taking a long view, investing in research, and advocating for systemic changes, usable and effective trait-based models for restoration can be developed.
- Successful research and implementation will integrate perspectives from across the research to practitioner spectrum.

Introduction

In a recent opinion article for the special issue "Young voices and visions for the UN Decade of Restoration," we explored why functional traits—a concept that has become widespread in ecological research—are underused in the practice of restoration (Merchant et al. 2023). We define functional traits as morphological, physiological, and phenological characteristics that impact fitness via effects on growth, reproduction, and survival (Violle et al. 2007). In the ecology literature, the most useful functional traits are those that are quantitative rather than qualitative, in part because quantitative traits can reflect variability within species, have demonstrated links to plant performance, and can provide more detailed information in statistical modeling. We see traits as an important tool to develop restoration strategies as global change rapidly pushes systems away from historical baselines. Traits have been the subject of keen interest in restoration ecology research, but we ask, as others have, whether this research is helping inform practice and how we can do better.

In a response to our article, Gornish et al. (2023) assert that functional traits are already widely used in restoration. We appreciate this point. Both (Gornish et al. 2023) and our original paper (e.g. our Box 1) identify some excellent examples where restoration projects have benefited from the use of functional traits. While Gornish et al. (2023) argue that these examples are widespread, we emphasized that more can be done. We seek forward-looking solutions to better integrate and advance trait science in restoration practice. When do the extra efforts to measure and use functional traits (sensu Violle et al. 2007) measurably benefit restoration outcomes? How can these efforts be supported and made even more useful? Originally, we identified four reasons why functional traits may not have been widely considered in restoration activities and discussed how these barriers can be addressed (Merchant et al. 2023). Here, we extend these points to emphasize the opportunities for progress if these barriers are addressed. It might take some effort, revision, and intention, but we think it is worth trying.

A key piece in Gornish and colleagues' argument is the disconnect between science and management: they argue that researchers do not realize the widespread use of functional traits because researchers do not work with practitioners. While we are not aware of any database accounting for the number of restoration activities that use quantitative functional traits beyond

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the published literature, a deficiency that we hope to rectify in future projects, previous literature reviews have suggested that traits are not widely used prior to restoration establishment (Carlucci et al. 2020). While we have different experiences from the authors of Gornish et al. (2023), our experiences support the view that functional traits are not widely applied in restoration projects. In the cases where we have convinced our partners to join us in functional trait measures or plant trials based on functional trait assemblages, that information has often not proven to be of great help to them. In our experience (which we expect is shared by many), our partners have a deep knowledge of the qualitative characteristics of species that augment taxonomic knowledge. They often consider categorical traits or functions, for instance, choosing to seed a rhizomatous grass to stabilize soil or a drought tolerant species to combat increasingly frequent droughts. Knowledge of these non-quantitative traits (understood via great depth of local ecological knowledge) is used widely, as also illustrated in Gornish et al. (2023), and has made us wonder where and when additional quantitative knowledge is helpful. One of our prime issues with Gornish et al. (2023) is that they appear to focus on restoration examples that apply categorical traits (e.g. heat resistance, C3 and C4 grasses) and do not explicitly advocate for using quantitative traits on a continuous scale. A vast literature aims to use continuous quantitative trait measures (as in the TRY database; Kattge et al. 2020) to predict plant responses to climate, management, and disturbance (drought, grazing, hurricanes, etc.; e.g. Bullock et al. 2001; Anderegg et al. 2016; Jimenez-Rodríguez et al. 2018) as well as effects on ecosystem functioning (e.g. soil stabilization; Faucon et al. 2017). The premise is that quantitative functional traits can provide useful information to managers in addition to non-quantitative traits, particularly considering the large amount of time these measurements take. The very fact that practitioners do seem to find categorical traits useful, combined with the growing availability and expertise in data and computing, seems to indicate a potential of quantitative functional traits that is only beginning to be realized. We believe that there are many more advances that need to be made before quantitative functional traits can become reliable and precise predictors of performance and ecosystem function.

Where Do We Go From Here?

Our opinion is that we should not be content with where the intersection between functional trait ecology and ecological restoration is currently, and in the spirit of the special issue in which our original article appeared—"Young voices and visions" for the future, we envision several ways in which we can make progress.

First, let us be ambitious and expand the field beyond the status quo. We need to commit to learning opportunities at the interface of functional trait ecology and ecological restoration. There are several areas that need to be explored further to better understand where functional traits may be better utilized in restoration. Recent advances in trait frameworks that aid in species selection based on restoration targets (Ostertag et al. 2015; Laughlin et al. 2018; Carlucci et al. 2020) demonstrate the potential for trait-based species selection models in restoration. For example, Ostertag et al. (2015) used quantitative plant traits to design novel restoration communities and found that these communities can lead to benefits in their nutrient cycling and resistance to invasion (DiManno et al. 2023). As noted in our original article, reaching the point where these quantitative trait-based frameworks are useful will require an extensive effort to resolve uncertainty related to context-dependency, build predictive models, and refine these models using a priori tests (Fiedler et al. 2018; Carlucci et al. 2020). Though these frameworks will require significant time and resource investment, we believe this work is worthwhile. Other places where we are excited to see the field progress are the use of traits to guide seed sourcing and development of functionally diverse plant materials (Coutinho et al. 2023) and the use of remote sensing to measure traits and monitor restoration (McKenna et al. 2023).

Let us be willing to embrace a variety of approaches. Functional trait work is better suited to some ecological restoration contexts than others. We need to increase our understanding of when the extra effort required to measure traits is worthwhile and translates to improved restoration outcomes, and when investing time and resources in other methods might achieve objectives more efficiently. Researchers often seek to understand traits as quantitative measurements that can be used to predict how species will respond to environmental changes and contribute to ecosystem functioning (Funk et al. 2017). Yet, there are also many cases where traits can and should be used in qualitative ways (Carlucci et al. 2020), without a need for quantitative measurements. Characteristics such as cool- versus warm-season phenologies, drought or grazing tolerance, and habitat affinities have proven invaluable for designing restoration projects (Naveh 1975; Padilla et al. 2009). Quantitative functional traits should be considered just one tool in the restoration toolbox, and work on functional traits needs to prioritize the areas where the trait approach can most improve restoration outcomes. For example, traits are particularly well suited for addressing process-based restoration goals or designing climate resilient ecosystems as climate change pushes us past historical baselines.

Let us be willing to work together. One way that the recent proliferation of functional trait research in restoration can be translated more widely into, and become more relevant to, restoration planning and practice is with greater collaboration between researchers and practitioners. Producing knowledge that builds capacity for testing functional trait applications in restoration requires co-production and extensive exchange among researchers, practitioners, policy, and plant production perspectives. There are several ways in which these efforts can be facilitated: policy that emphasizes co-production, incentives for innovation and trialing new approaches, including restoration experiments and long-term monitoring, development of tools that allow greater access and utilization of trait data, and new partnerships that build off the rich knowledge of both restoration practitioners and researchers (Heger et al. 2022). It has never been the goal for functional trait information to replace local ecological knowledge, whether obtained through years of experience, in-house experiments,

or tribal/traditional knowledge that is transferred across generations. Instead, local ecological knowledge is a vital source of context-specific information to support trait-based research, which in turn can lead to more general predictions and insights for ecological restoration across contexts. This exchange will require building close collaborations and mutual respect between researchers and practitioners. While many of our initial collaborations with practitioners have shown that the path to incorporate functional trait measures will not be straightforward, it is an iterative process, and with each new step, more doors open. Gornish et al. (2023) argue that these new initiatives will not be feasible, either because researchers and practitioners might not share the same goals or that these efforts will be hard to fund. Yet, similar successes in adaptive management and conservation (Fernandez-Gimenez et al. 2008; Wilmer et al. 2018; Lynch et al. 2022) make us think otherwise.

Gornish et al. (2023) suggests that one potential role for co-produced research is accessible tools. In fact, we provided the same suggestion (Merchant et al. 2023). However, it is worthwhile to think about what this looks like. One big challenge with marrying research and practice is the difference in time scales. Research is often slow moving compared to the pressing needs of practitioners. We should take lessons from successful projects that highlight the role researchers can play in co-producing research. For example, by investing in structured long-term relationships and listening to community partner input, researchers generate tools that can be used to quickly process data and present partners with near real time metrics with which to make decisions (Wilmer et al. 2018).

A Turning Point in Research and Restoration Practice

We feel that the world of trait-based restoration ecology is at a turning point. For decades, our knowledge of functional traits in ecology generally has been growing and maturing. The relatively recent interest in functional traits in restoration research comes with the opportunity to think critically about how research can better translate into practice going forward. We live in an age where quantitative metrics are leading to increased efficiency in nearly all fields, from advertising to agriculture. We see promise for more widely applying quantitative functional traits in restoration planning and monitoring to maintain and rebuild diverse, resilient ecosystems in the face of global change. However, we realize this future may require rethinking incentives, building different partnerships, and trying new things. We appreciate the conversation continued by Gornish et al. (2023), as they have different perspectives and experiences. We hope that this exchange can help catalyze conversation and action to build the potential of functional traits in the future of restoration.

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