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RESPONSE ARTICLE

Functional composition trajectory: a resolution to the debate between Suganuma, Durigan, and Reid

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The selection of ecological indicators is an important step toward more effective restoration monitoring. The debate between Reid (2015) and Durigan and Suganuma (2015) regarding the usefulness of species composition for monitoring restoration trajectory is timely and salient, but it lacks a middle way proposal to balance ecological relevance and practical viability. We propose a way forward to resolving this debate, namely using easily measurable functional traits, a type of compositional measure, as an indicator. Assessing functional composition trajectory may help overcome some limitations with taxonomic identification and provide more meaningful outcomes to evaluate restoration success.

Key words: forest succession, functional ecology, functional traits, monitoring protocols, restoration monitoring, restoration success

Implications for practice

- Basal area and abundance provide a more reliable evaluation of restoration success if combined with taxonomic and/or functional composition indicators.
- Using weighted averages of simple functional traits is a feasible indicator of forest composition and provides more meaningful information for assessing restoration goals than species richness.
- Native and non-native species have to be distinguished when measuring composition and structure attributes in restoration projects.

In recent years, extensive commitments to forest restoration are being made at the regional, national, and global scales (Suding et al. 2015), which will require extensive resources to implement (Menz et al. 2013). Developing monitoring protocols is important to evaluate whether specific project goals and objectives have been achieved, to determine when and how to intervene to correct restoration trajectories, and to learn from unsuccessful projects in order to more efficiently allocate resources in the future. It is critical to carefully selecting monitoring parameters that evaluate whether forest restoration projects are following a trajectory toward reference ecosystems, but that recognize typical budgetary constraints for monitoring and do not require highly specialized skills to implement (Holl & Cairns 2002; Chaves et al. 2015).

Suganuma and Durigan (2015) recommend basal area, species richness, and abundance and richness of naturally regenerating seedlings as the best indicators of tropical forest restoration. Their recommendation is based on the argument that these measures follow a predictable trajectory during succession and are feasible to measure (Durigan & Suganuma 2015; Suganuma & Durigan 2015). We agree with the critique of Reid (2015) that these measures alone indicate little about whether the composition of the site is approaching a reference ecosystem, a common goal of most forest restoration projects. For example, basal area increases in exotic species tree plantations or when invasive tree species colonize a site (Lugo et al. 2012; Van Auken & Bush 2013), situations which do not represent restoration success. Moreover, alpha species richness can increase in a system due to proliferation of common ruderal species (Tabarelli et al. 2012) and may not indicate that a site is approaching reference forest composition. Hence these measures need to be combined with compositional indicators of forest recovery, but Reid (2015) did not provide suggestions for how to practically measure and evaluate species composition in the context of tropical forest restoration trajectories.

Durigan and Suganuma (2015) respond to Reid (2015) that species composition is not a realistic indicator because its lack of predictability in highly diverse tropical forests. We agree; extensive data on natural succession suggest that vegetation composition is highly stochastic based on both dispersal and establishment limitation (Norden et al. 2015). Moreover, even reference forests within the same landscape may have low similarity in species composition (Suganuma et al. 2013; Chazdon 2014). Durigan and Suganuma (2015) also contend that species composition is not a practical indicator because of the taxonomic expertise required to identify the myriad tropical tree species, despite the fact that their proposed measures of total

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and recruit species richness require taxonomic skills, which is an even greater challenge when considering saplings. They recommend using morphospecies to ease the plant identification challenge. However, we are not aware of studies demonstrating that plant morphospecies richness is a good predictor of actual plant species richness in tropical forests. It is quite possible that morphospecies richness could underestimate species richness as many species, particularly in the Lauraceae and Myrtaceae, are indistinguishable as saplings, or overestimate native forest species richness, due to large numbers of non-native, disturbance-adapted species.

We propose a way forward to resolving this debate, namely using easily measurable functional traits, a type of compositional measure, as an indicator. Many studies show that certain functional traits, such as shade tolerance (Dent et al. 2013), seed size (Lohbeck et al. 2013), wood density (Plourde et al. 2014), and proportion of animal-dispersed seeds (Liebsch et al. 2008), show predictable trajectories during tropical forest recovery. In fact, Suganuma and Durigan (2015) report that the proportion of animal-dispersed, shade tolerant, and slow growing species follow a predictable trajectory over time in the planted Atlantic forest restoration chronosequence they studied. But, surprisingly they do not propose any of these traits amongst their recommended indicators. These traits indicate a progression from pioneer to later-successional, mature forest species that are typical of reference forests. Information regarding seed size and dispersal mechanisms and wood density (which is generally inversely related to growth rate) is available for many species already (Chave et al. 2009; Kattge et al. 2011), and, in cases where these data are not available, they are relatively easy to collect for common species.

Using an integrated measure of simple functional traits (e.g. weighted averages sensu Dent et al. 2013) can be a more practical and informative approach for monitoring tropical forest restoration than estimating species richness for a few reasons. First, species richness is highly influenced by rare species, which are very numerous in tropical forests and more difficult to identify. Using functional traits may require species identification, but the overall weighted average of a functional trait will not be strongly affected by the lack of identification of a few rare species and thus it likely to be more representative of ecosystem recovery than species richness.

Second, in many cases identification to family or generic level is sufficient to know the seed dispersal syndrome and range of wood specific gravity depending on the biogeographical region. For instance, all Neotropical Lauraceae and Myrtaceae species (except one species) are animal-dispersed and most of them have high values of wood specific gravity. Thus, if a plant can only be identified to genus or family often the trait data can be estimated given the phylogenetic conservatism of most traits (Wiens et al. 2010).

Third, dominant tree species with high influence on forest structure and functioning are put at the same level of importance as rare species in species richness assessments. The outcomes provided by the use weighted averages of functional traits can be more meaningful than species richness to assess some of the ecosystem functions that are targeted in restoration projects (e.g. wood specific gravity for carbon stocking, proportion of animal-dispersed trees to attract fauna). There have been repeated calls to move from vague restoration goals, such as restoring ecosystem services, to specific functions to be achieved according to the context in which restoration is implemented, like favoring water infiltration to enhance water supply to human populations in the dry season (Stanturf et al. 2014). The use of carefully selected functional traits as restoration targets can help practitioners to better assess restoration success according to their main goals and needs. The specific analytical procedures used to integrate functional trait values at the site level must be carefully considered, but a detailed discussion is beyond the scope of this short article.

In addition to using functional traits as a compositional indicator, we contend that the indicators proposed by Suganuma and Durigan (2015) would be more meaningful if they were restricted to only native species, which was not specified in their proposal. This modification comprises further justification for the need to identify species rather than morphospecies when monitoring.

Most forest restoration projects aim to restore some semblance of the species composition prior to disturbance. Thus, indicators are needed to evaluate whether this goal is being achieved. In conclusion, we think that using some modified indicators suggested by Suganuma and Durigan (2015) such as basal area of native trees and abundance of native recruits, and combining those with simple functional traits, that have been demonstrated to show predictable trends during succession, presents a promising approach to monitoring the degree of success in forest composition targets that should be widely tested.

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