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POLICY ARTICLE

On the need of legal frameworks for assessing restoration projects success: new perspectives from São Paulo state (Brazil)

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Despite growing worldwide commitment to large-scale ecosystem restoration, national public policies on restoration are few, and those that exist tend to be vague. Brazil and especially São Paulo state stand out. In a pioneering attempt to improve restoration projects and their outcomes, the Secretariat for the Environment of the State of São Paulo has enacted a legal instrument to drive planning and to assess whether the goals and targets of mandatory ecological restoration are being achieved. Regardless of the restoration techniques applied, the effectiveness of mandatory or public-funded projects will henceforth be assessed by using three ecological indicators: (1) ground coverage with native vegetation; (2) density of native plants spontaneously regenerating; and (3) number of spontaneously regenerating native plant species. We analyze how this science-based legal framework is expected to promote greater restoration success, improve cost-effectiveness, and help bridge the all-too-familiar knowledge-action gap in environmental policies. Notably, scientists, professionals, public agents, and stakeholders from different institutions have collaborated to advance the refinement and rolling out of this legal instrument. By 2037, it is expected that more than 300,000 restoration projects will be carried out in São Paulo state and monitored using this set of indicators. We also suggest that this approach could be usefully applied to the growing number of ecological restoration programs being carried out worldwide, especially in the context of offset policies intended to achieve serious compensation for environmental degradation or loss of biodiversity.

Key words: cost-effectiveness, ecological indicators, ecological restoration monitoring, evidence-based practice, restoration success, science–policy interface

Implications for Practice

- Mandatory restoration, public-funded initiatives, biodiversity offsetting, and other mitigation actions on public and private lands all require measurability and criteria to assess the outcomes of ecological restoration projects.
- A set of evidence-based ecological indicators integrating structure, diversity, and ecosystem functioning, such as that incorporated in the new legislation reported on here, can be effectively used to verify whether the targets of mandatory projects are being achieved.
- Thanks to better comprehension of restoration processes, freedom to adopt different techniques, reduction of costs, and increasing use of evidence-based practice, adaptive management interventions can also be refined for application when minimum standards for each ecosystem type are not reached, thus leading to more successful restoration projects.

Introduction

Ecological restoration of degraded ecosystems is now widely recognized as a key component of both conservation and sustainable economic development programs (Neßhöver et al. 2011; CBD 2012). Increasingly, scientists and practitioners, as well as those engaged in formulating government policy, administration of restoration programs, and evaluation of their actions, will be called upon to assess, improve, and scale up existing programs, and to create new, more effective initiatives. The 168 nations that ratified the Hyderabad Call of the U.N. Convention on Biological Diversity (CBD 2012) have committed to formulating and meeting national targets to restore—or at least begin restoring—15% of all degraded ecosystems in their

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respective territories by 2020. Concurrently, initiatives in Brazil, Canada, China, Colombia, Ecuador, Panama, South Africa, the European Union, the United States, and elsewhere, clearly show that large-scale ecological restoration is emerging as a global priority (Aronson & Alexander 2013; Suding et al. 2015).

A key to internalizing the costs of these ambitious restoration goals will be to promote national, state, and municipal policies supporting on-the-ground ecological restoration projects (Brancalion et al. 2013). Indeed, legal instruments have been the main drivers of ecosystem restoration worldwide (Ruiz-Jaen & Aide 2005) and certainly should be used to promote future restoration efforts. However, few policies have been developed for regulating and financing ecological restoration, partly due to a lack of clarity on how to monitor and evaluate progress. Clearly, major increases in financial allocations toward refining and upgrading restoration science, business, and practice will require much more detailed valuation and evaluation methods and techniques (Blignaut et al. 2014), including estimates of cost-effectiveness (Aronson et al. 2010; de Groot et al. 2013), socioeconomic benefits (BenDor et al. 2015), and ecological outcomes.

In this context, current legislation and ongoing dialogues and debates among scientists, economists, conservation NGOs, and state government policymakers in Brazil provide a valuable case study. Ongoing work on the science–policy interface in São Paulo state is of particular note (Joly et al. 2010). Policymakers there have developed pioneering legal instruments for regulating ecological restoration projects, of which the benefits and limitations were previously highlighted and debated by a large group of scientists (Aronson et al. 2011). Such debates were triggered by the overall perception that many projects did not result in self-perpetuating ecosystems and that the reasons for failures were not fully understood (Rodrigues et al. 2009). Inefficient control of invasive grasses and leaf-cutting ants, water deficit in the dry season, and the low survival and slow growth of inadequate seedlings planted were among the possible explanations for unsuccessful projects (Durigan & Melo 2011). There was an expectation that improved legal instruments could drive restoration planning and monitoring toward more successful initiatives.

In this paper, we provide an update on the ongoing discussions, and the most recently enacted regulation, regarding ecological restoration in São Paulo state, including the numerous ecosystem types comprising the Atlantic Forest (*Mata Atlântica*) and *Cerrado* (Brazilian savanna) biomes, both of which are recognized as global biodiversity hotspots (Mittermeier et al. 2011). Examination of this pioneer legal instrument may shed light on the importance of establishing science-based legal goals for mandatory or public-funded restoration projects, and pave the way for the creation of similar legal instruments elsewhere to safeguard societal interests when restoration is used to meet legal requirements, including the mitigation or offsetting of environmental damages, or when it is financed by public money, either on public or on private lands.

As noted above, social, socioeconomic, and political costs and benefits of, and obstacles to, effective large-scale restoration work must ultimately be considered as well as the ecological factors. However, in this paper, we concentrate on the most recently enacted regulation regarding ecological restoration in São Paulo state, which only addresses ecological criteria for success. One important bridge toward more holistic planning and evaluation of truly effective large-scale restoration that is embedded in the new legislation is the concept of helping the target ecosystem undergoing restoration recover resilience and self-sustainability, as we discuss near the end of the section "Legal instruments requiring restoration and the potential role of indicators."

Legal Instruments Requiring Restoration and the Potential Role of Indicators

Brazil has a long history of mandatory restoration, starting with the National Environmental Policy enacted in 1981, imposing compensation for environmental damage linked to development projects. New regulations followed that first instrument (an historical overview on legislation and practice of ecological restoration in Brazil is presented in Appendix S2, Supporting Information), culminating with the Law of Native Vegetation Protection and Restoration—the so-called New Forest Code—Federal Law 12.651/2012—that reinforced the legal restoration requirements (Soares-Filho et al. 2014). Besides the huge increase in physical areas to be restored, since 1998 the expectation of restoration in Brazil has shifted from protecting urgently needed natural resources to also include the recovery of habitats and biodiversity (Durigan & Melo 2011). In addition, the need for restoration in grasslands, savannas, and other biomes are now more clearly addressed, dramatically increasing the challenges for those in the science, policy, and practice sectors.

The enactment of the "New Forest Code" in 2012 brought important changes in the policy arena. In spite of many setbacks in environmental protection, this law reinforced the need to restore degraded lands on private landholdings: it is calculated that there are 21 million hectares to be restored at the national scale (Soares-Filho et al. 2014). Mandatory restoration is concentrated in Areas of Permanent Preservation (APP), mainly established along watercourses, riparian buffers, steep slopes, and hill tops, and in Legal Reserves (LR). These landscape units represent a percentage of every landholding, ranging from 80% in the Amazon region to 20% elsewhere, in most of the country, which must be covered by native vegetation.

Through the new Forest Code, an integrated online protocol for checking on environmental legal compliance was established for the first time in Brazil. All landowners are now obliged to register their properties in an online system known as "The Environmental Rural Register," in which all APPs and LRs—whether currently covered or not by native vegetation—have to be declared and delimitated in a map. For the State of São Paulo, it is expected that approximately 300,000 landholdings will be registered by 2016. Owners of landholdings with less native vegetation cover than that required by law (most of them) are obliged to implement restoration, and are encouraged to adhere to the "Environmental Regularization Program," which provides incentives to farmers, such as authorization to partially maintain cultivated areas in riparian zones, and availability of rural credit after 2017, whereas these opportunities will not be available to those not complying with the law.

Targeted APPs and LRs must be restored in the 20 years following a landowner's adherence to the "Environmental Regularization Program." However, the Forest Code does not stipulate what is meant by "restored," lacking clarity on which structural, functional, and compositional levels or characteristics should be attained in order to fulfill the legal requirements. This is an important policy gap that may hamper effectiveness of the law. Given the huge size and heterogeneity of Brazil, each state government must play its role in establishing regional legal instruments and determining and regulating reference levels of restoration success for each ecosystem type.

How can this be achieved? Evaluating ecological restoration success should in principle not include only ecological variables but also socioeconomic goals and outcomes (Aronson et al. 2010; Aronson et al. 2011). However, criteria to evaluate success in projects required by law must logically be related to proximate restoration goals. In light of the stated goals of the Brazilian legislation on restoration, namely recovering biodiversity and ecosystem services, restoration success in this country, as almost everywhere else (Wortley et al. 2013), has been primarily assessed using structural and compositional indicators of ecological processes. In this sense, vegetation indicator monitoring is given priority as a result of their (1) relative ease of implementation; and (2) validity as proxies for other ecosystem attributes and ecological processes (Ruiz-Jaen & Aide 2005), thus integrating important variables whose measurement would be too costly or time-consuming for inclusion, a key attribute for a good ecological indicator (Dale & Beyeler 2001).

Vegetation structure, which can be measured by vegetation cover (Bartelink 1997), is directly related to improvement of environmental conditions, colonization by plants and animals, and ecological processes such as nutrient cycling, rain interception, and control of invasive plants (Ruiz-Jaen & Aide 2005; Llorens & Domingo 2007). Numerous ecosystem services, such as carbon sequestration and protection of soil and water resources, also depend directly on vegetation structure. In particular, abundance and species richness of spontaneously regenerating plants are readily measurable, and provide very direct evidence of an ecosystem undergoing restoration progressively accruing resilience and self-sustainability (Haeussler et al. 2007; Norden et al. 2009; Reid & Holl 2013; Suganuma & Durigan 2015).

The challenge of evaluating restoration success requires cooperation among scientists, policymakers, and experienced practitioners to identify an appropriate and user-friendly set of ecological indicators and associated protocols for monitoring and evaluation. In the state of São Paulo, the Secretariat for the Environment (SMA in Portuguese) is leading the process. Ongoing interaction among policymakers and scientists has provided a new legal approach for guiding restoration success, focused on the ecological "results" of restoration, rather than simply assessing the extent of implementation. This pioneering policy approach, described in the next section, may inaugurate an important stage in large-scale restoration governance, and thus merits attention.

Putting Ecological Indicators to Work: An Innovative Legal Instrument to Assess Restoration Success

Aiming to gather field data, select good indicators, and produce reasonable and readily applicable protocols, the Secretariat for the Environment organized a workshop in 2010 (Uehara & Gandara 2011) as part of the "Ecosystem Restoration of Riparian Forests in São Paulo" project supported by the World Bank, and also co-organized two workshops with the Atlantic Forest Restoration Pact (Melo et al. 2013). In addition, new research was supported (e.g. Suganuma & Durigan 2015) and several meetings with scientists and public agents were held to aid in the development and enactment of a new legal instrument based on ecological outcomes, namely Resolution SMA 32/2014 (see Appendix S1 for full translation).

As a product of the above-mentioned meetings and workshops, three core indicators were selected for Resolution SMA 32/2014: (1) *Ground coverage with native vegetation* (percentage); (2) *Density of native plants spontaneously regenerating* (number of individuals per hectare; height $H > 50$ cm and circumference at breast height, CBH < 15 cm); and (3) *Number of spontaneously regenerating native plant species* (number of species with $H > 50$ cm and CBH < 15 cm).

One of the principal goals of ecological restoration, as stated in the above-mentioned SMA Resolution, is to help the target ecosystem recover self-sustainability (see Fig. S1; cf. Suding et al. 2015). Restoration success is therefore judged on progress achieved in recovering a certain minimum level of complexity to trigger and sustain all the ecological processes that drive self-organization, and thereby confer capacity for adaptation to changing environmental conditions, through evolving ecosystem structure, composition, and functioning.

In Figure 1, we illustrate the theoretical basis of the three selected ecological indicators, a combination of attributes related to structure and biodiversity that may reveal whether or not a presumed threshold of self-sustainability has been crossed. Compliance with the SMA Resolution will depend on ecosystem assessment demonstrating that this threshold was crossed, through attainment of minimum reference values for all three above-mentioned indicators. Projects should, in principle, be monitored until it happens.

Accordingly, the new SMA Resolution defined a monitoring schedule consisting of surveys to be made by the project manager starting with visits planned 3, 5, 10, 15, and 20 years after restoration work is initiated. However, if project completion is verified prior to 20 years, through attainment at any time of all reference values corresponding to each ecological indicator assessed for each ecosystem type (see Table S1), no more surveys are needed.

For each monitoring phase, three "adequacy levels" were established for each ecological indicator, namely, (1) critical range, when the acceptable intermediate score has not been attained, leading in turn to requirement of readjustments in the

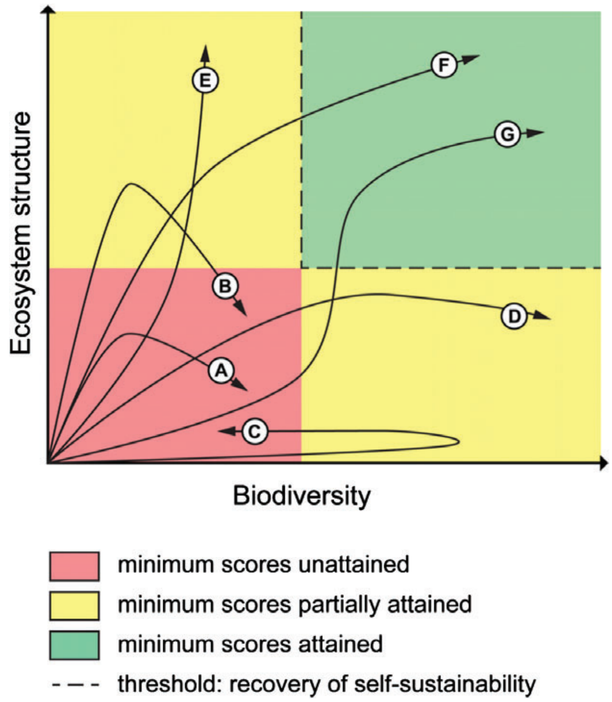

Figure 1. Varying trajectories of ecosystems undergoing restoration, illustrating the threshold used to verify the completion of restoration projects according to the new legal framework of São Paulo state, Brazil—The threshold is considered crossed only when the reference values for all three selected ecological indicators have been attained. The arrows (A–G) represent possible trajectories of ecosystems undergoing restoration, in terms of structure (in this case, vegetation cover and density of native plants spontaneously regenerating) and biodiversity (in this case, number of native plant species spontaneously regenerating). Trajectory A represents an ecosystem that has not reached the minimum structure or biodiversity thresholds required for self-sustainability; B: the ecosystem reached and surpassed the minimum score for structure, but nonetheless returned to the red "condition" (minimum scores unattained) subsequently; C: the ecosystem attained the minimum biodiversity threshold, but returned to the red condition subsequently. Trajectory D surpassed the minimum biodiversity threshold, but not minimum structure, and potentially can shift to trajectory C. Trajectory E surpassed the minimum structure threshold, but not that of minimum biodiversity, and potentially can shift to trajectory B. Trajectories F and G surpassed the threshold for self-sustainability, which requires certain levels of both structure and biodiversity. Ecosystems that reached the green zone are not expected to return to the yellow or red conditions, unless a major, human-mediated disturbance occurs.

project design; (2) minimum range, when the acceptable intermediate score has been attained, but corrective measures should be carried out to avoid failures in future; and (3) adequate range, when the desired intermediate score has been attained. During the monitoring period, the projects are considered acceptable only when all three indicators attain level *b* (that works as a warning) or *c* (the intermediate goal), whereas *a* requires project adjustment and eventually leads to penalties. Table S2 presents a more concrete example on how to apply the adequacy levels during the monitoring period: considering a hypothetical restoration project within the Atlantic Rainforest biome, it shows the expected results for each ecological indicator, for each period of time (for full details, see Appendix S1).

To gather and manage all the data to be produced by monitoring over the coming decades, the Secretariat for the Environment created an online Ecological Restoration Supporting System (SARE), wherein restoration projects are registered and monitored by practitioners. The general guidelines for the monitoring methodology come from the "Monitoring Protocol" published by the Atlantic Forest Restoration Pact—AFRP (PACTO 2013), of which the Secretariat for the Environment is a member.

In short, we consider that Resolution SMA 32/2014 defines concepts compatible with the Brazilian federal requirement of "ecosystem recovery," which will be assessed using three ecological indicators over a maximum of 20 years. When acceptable scores for each monitoring phase are not attained, corrective measures will be required. Guidelines and evaluation parameters shall be applied to publically funded restoration projects as well as to compulsory projects. Responsibility for restoration commitments in most cases lies with landowners, but could devolve either to companies requiring permission to proceed with development projects, or to those having negligently caused environmental damage. Such an online information system should help landowners, practitioners, and public agents to gather, monitor, and evaluate project data related to the above-mentioned ecological indicators. Notably, stakeholders, scientists, professionals, and public agents from different institutions have voluntarily collaborated to advance the refinement and rolling out of this legal instrument.

Perspectives and Challenges

The innovative approach adopted for creating the new São Paulo state Resolution regarding ecological restoration may enhance restoration effectiveness in three ways: (1) *supporting better comprehension of the restoration process by landowners and professionals* in charge of implementing projects, moving beyond basic reforestation toward a science-based approach targeting self-sustaining ecosystems; (2) *reducing restoration costs*. As previous regulation had neglected the importance of natural regeneration processes, practitioners tended to use costly restoration plantings for fulfilling legal requirements in the first 2 years, even though less expensive and more effective strategies were available. Furthermore, practitioners and landowners will now have a more favorable legal environment for seeking innovative solutions and improving cost-effectiveness; thus (3) *restoration projects may become more successful* in ecological terms, and in the delivery of ecosystem services, thanks to better comprehension of restoration processes, freedom to adopt different techniques, reduction of costs, and increasing use of evidence-based practice, as practitioners and scientists are encouraged to refine adaptive management interventions for application when minimum standards for each ecosystem type are not reached.

This new perspective is also timely in regard to the growing number of restoration programs around the world required in the context of offset policies, in which large amounts of financial resources are invested without necessarily obtaining the desirable outcomes for minimally compensating environmental degradation or loss of biodiversity (Maron et al. 2012). This new legislation approach will however bring many challenges. First, restoration ecologists must continuously study the effectiveness of the ecological indicators selected as proxies of restoration success, as they will be henceforth widely applied, considering the standards for each ecosystem type along the time line of a restoration project. Second, policymakers must face the challenge of dealing with an honor system, whereby landowners are expected to voluntarily report their restoration obligations, without waiting for field agents to audit compliance and on-the-ground results. As practitioners will monitor projects in the field and upload their results in a web-based system, law enforcement agents will have to find solutions for checking the results reported, penalizing irregularities, and promoting an honest, transparent use of the system. New technologies and software must be developed for confirming results and guiding field visits, such as remote sensing of vegetation cover, and governance programs for avoiding fraud and conflicts among actors. Those tools would also be useful for implementing desirable policies on payment for ecosystem service programs. Finally, a higher investment in communication and integration is necessary to promote creativity, improve cost-effectiveness, and further consciousness-raising and consensus-building in all sectors relevant to the state-wide effort. The hoped-for outcome would be a dual bottom-up and top-down approach that could lead to quantum leaps forward.

With growing investments in ecosystem restoration worldwide, it is essential to create a favorable policy environment for achieving desired outcomes in restoration programs, especially with regard to biodiversity conservation and ecosystem services provisioning. Otherwise, restoration advocates may lose momentum in their campaign and efforts for the recognition of ecological restoration as a key activity for society. Legal frameworks for assessing mandatory restoration projects can be a valuable tool, especially if the over-arching principles of resilience and self-sustainability are taken on-board from the outset, and it is the case here. We hope that the example reported here may be useful for supporting the creation, or refinement, of similar legal instruments elsewhere to safeguard societal interests associated with effective and sustained ecosystem restoration.

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Supporting Information

The following information may be found in the online version of this article:

Figure S1. Varying trajectories of ecosystems undergoing restoration through time with respect to a putative threshold of self-sustainability, as envisioned in the new piece of legislation regarding ecological restoration in São Paulo state, Brazil.

Table S1. Reference values used to verify recovery of various ecosystems undergoing mandatory restoration, according to the new legal instrument regarding ecological restoration in São Paulo state, Brazil.

Table S2. Intermediate reference values, in the case of Atlantic Rainforest restoration, according to the new legal instrument regarding ecological restoration in São Paulo state, Brazil.

Appendix S1. Resolution SMA 32/2014. It establishes guidelines, criteria and the general protocol to be employed for the practice of ecological restoration in São Paulo state, Brazil.

Appendix S2. Legislation and practice of ecological restoration in Brazil: historical overview.

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