

## **TBD for Reproducibility Grant**

### **Proposal Ideas**

1. Consider having 2-3 replication by the PIs already identified for implementation in Year 1. Then in Year 2, once the word has spread and we can show how it would work, we can recruit PIs to do 2-3 of the others on the list. This guarantees we get the ball rolling in Yr 1 (my concern is limited volunteering for 'risky' project unless proof of concept).

### **Follow-up: Potential Partners / Co-PIs / Senior Personnel**

1. ATBC
2. EiC *Biotropica*
3. Nosek, Arrington, Center for Open Science
4. Specialist in Assessment, Social Psychology, or Organizational Behavior
  - Kate Ratliff: <http://www.kateratliff.com/>
  - Nia Morales: <https://tinyurl.com/yeyv29x6>
  - Fiona Fidler: <https://fionaresearch.wordpress.com/about/>
  - Nicole Gravina: <https://people.clas.ufl.edu/ngravina/>
  - Amir Erez: <https://warrington.ufl.edu/directory/profiles/5084/>
  - Gwendolyn Lee: <https://warrington.ufl.edu/directory/profiles/5067/>
5. Potential Partner co-funding projects in Brazil: Inst. Serrapilheira. Contact is Kleber Neves (co-founder of Brazilian Reproducibility Initiative)

### **Approach: how many & which replications**

1. Open call to replicate any from list of 10, **OR**
2. Line up commitments in advance to replicate 3-5 specific projects, **OR**
3. Hybrid Approach: have 2-3 lined up in advance for 1st Round, then Open Call once Project is established **AND/OR**
4. Involvement of OTS or other repeated field courses (e.g., Guanacaste for *Acacia*)?

### **Activities**

1. Replication Grants (administered by ATBC)
2. ATBC Symposium or Session to Introduce Project
3. Online and Meeting Training Workshops (design, reproducible science, R)
4. Meta-analysis workshop with Replication Leaders
5. Assessment

### **Personnel / Financial**

1. EB & SC: Project Oversight, Workshops
2. Assessment PI
3. Postdoc or GA conducting Assessment
4. ATBC Treasurer (disbursements)
5. *Biotropica* Editor (publication oversight)
6. Replication Leaders: Established Researchers? Postdocs or GAs leading 1-2 replications?

### **Financial**

1. PI Salary Support: EB, SC, Assessment PI, BN
2. GAs for EB and SC to lead a replication
3. Replication Grants (as subcontract to ATBC)
  - bank fees
  - stipends for Editor and Treasurer for additional work

- stipends to incentivize Replication Leaders
  - ATBC Overhead
4. Travel to Meetings
  5. Workshop Materials
  6. Equipment & Computing Resources (Zenodo, Github, Slack, etc)
  7. Dryad and Publication Fees

# REPRODUCIBILITY AS A CATALYST FOR TRANSFORMATIVE INSIGHTS AND CULTURAL CHANGE IN FIELD BIOLOGY

## PROJECT DESCRIPTION

Reproducing the outcome of prior studies is a fundamental method for advancing scientific research. While replications are often conducted to confirm experimental results, they also lead to conceptual advances by providing data with which scientists refine classical theories and accelerate the development of novel ones. While biologists in lab-based disciplines are increasingly embracing replication as a research method, those in ecology and other field-based disciplines have been reluctant to do so. *We are proposing to design and assess the methods for replicating ecological studies.* We will do so by supporting, coordinating, and evaluating the replication of fundamental field studies in sites across the globe. This project will advance biology in three ways: first, by providing data with which the scientific community can directly assess Replication's value as a method for making conceptual advances. Second, by testing and refining the infrastructure required to implement Replications, including individual and institutional incentives, training, publications, and tools for collaboration and data management. Most importantly, it could lead to the adoption of replication as an integral method for conducting rigorous, field-based research. This would catalyze a transformative cultural change in a scientific discipline central to studying the impact of human activities on biodiversity and ecosystem services.

## CONCEPTUAL FRAMEWORK

A hallmark of science is replicability (Voelkl et al. 2020). Replication is collecting new data to test a claim from prior research (Nosek and Errington 2020a). Replication advances credibility of research by increasing confidence in the reliability of a finding, improving the precision of estimated effects, or identifying how our understanding of conditions needed to observe a finding might be limited. Corroborating findings with replication helps eliminate mistakes and questionable research practices and speeds scientific progress (Fraser et al. 2018, Redish et al. 2018), which is why it is fundamental to the scientific method (Popper 2005).

A surge of efforts to replicate the results of fundamental studies in fields ranging from chemistry (Bergman and Danheiser 2016) to the biomedical sciences (Errington et al. 2014, Amaral et al. 2019) reflects a general concern that this core principle of science may not be operating as well as expected in practice. For example, the Open Science Collaboration Collaboration (2015) replicated 100 psychology findings and observed successful replication of results for less than 40% of them. Observing differences between original studies and replications can be beneficial, however, by leading to the development of generative theory to account for the observed differences. For example, in exploring a failure to replicate one could identify previously unappreciated factors critical for observing the phenomenon of interest (Collaboration 2015). Of course, it is also possible that the original result was a false positive, in which case nothing would explain why the original study observed a finding but the replication did not. Over time replications either build confidence in and mature the theoretical understanding of a phenomenon, or they render the finding irrelevant because the conditions for demonstrating replicability cannot be identified (Nosek and Errington 2020a).

Field-based sciences such as Ecology, Behavior, and Evolution (EBE) could benefit from promoting replication (Kelly 2006, Huang 2014, Nakagawa and Parker 2015, Fidler et al. 2017), but the response of the EBE community to calls for adopting this research infrastructure has ranged from

tepid to skeptical (Editors 2016, Schnitzer and Carson 2016, Ives 2018). The reasons put forward by field biologists for not conducting replications echo the practical concerns put forward by scientists in other fields: a lack of incentives or professional rewards for carrying out replications, journals unwilling to publish the results of replicated studies, and concerns about efficient use of scarce research funding (Nakagawa and Parker 2015, Schnitzer and Carson 2016, Fidler et al. 2017). However, many also suggest a more fundamental and conceptual obstacle – that research in EBE is inherently impossible to replicate because it is carried out under unique biotic and abiotic conditions (Nakagawa and Parker 2015, Schnitzer and Carson 2016). Ironically, this skepticism is accompanied by the embrace of “distributed experiments” (Fraser et al. 2013, Borer et al. 2014), in which the same experimental manipulation is simultaneously replicated at geographically and ecologically disparate locations (e.g., Romero et al. 2020).

To be clear, there is no such thing as exact replication, regardless of discipline and research context. There will always be innumerable differences resulting from changes in season, laboratory conditions, historical circumstances, or the identity of participants. This is certainly true in an EBE context, in which the biotic and abiotic conditions under which field studies are conducted will never be identical. But scientific claims are not historical ones, for which a finding is presumed to apply only in the original context. Scientific claims are statements about regularities one expects to observe across contexts when certain conditions are met. That is why replication is formally defined as attempting to reproduce a previously observed result with procedures that provide no *a priori* reason to expect a different outcome (Schmidt 2009, Collaboration 2015, Nosek and Errington 2017). This is why replications in EBE do not have to be conducted under biotic and abiotic conditions identical to those of the original study; given our present understanding of the phenomenon, the new environmental context should not reveal something different from the original one (Nosek and Errington 2020a). Of course, the ‘present understanding’ can be wrong, which is why a replication that does not produce the same finding as the original study can be so useful for testing and advancing theory – it forces one to assess whether the original study could have been a false positive, if the replication might have been a false negative, or to generate hypotheses for why the studies had different outcomes. This assessment may be especially important in the context of management or conservation, where one seeks confidence in the original conclusions, rather than broad theoretical generality.

Moreover, it is important to emphasize that a study can indeed be replicated with a different species or in a different location (Nakagawa and Parker 2015, reviewed in Fraser et al. 2020). If the original claim is explicitly bounded by geography or species identity, then to qualify as a replication the methodology must respect those restrictions. If the original claim is more general, however, then the replication can in theory transcend geography and species identity within limits concordant with the extent of the original claim’s generality (Table 1). While replications are perhaps most straightforward to conceptualize when using species and methods identical to those in original study, they can be conducted with other systems if the replication design actively confronts the present understanding with a test that provides diagnostic information increasing or decreasing confidence in the original claim. Put another way, a replication is a theoretical commitment to specify a study design for which one expects the same outcome as the prior findings given our understanding of the phenomenon of interest (Nosek and Errington 2020a).

That said, expanding the domain of valid replications to include novel systems is conceptually exciting but requires exceptional rigor and *a priori* consensus regarding the study design and expected outcomes (Nosek and Errington 2020a). This challenge is further exacerbated if the theoretical expectations of the original study are underspecified, making it unclear if the claim

should in fact recur in different locations or species. Ambiguous expectations lead to asymmetric inference – while observing consistent evidence builds confidence in the original finding, failing to do so doesn't decrease confidence. Such asymmetric tests are therefore not replications. They are tests of generalizability (Nosek and Errington 2020a), which are useful for understanding the breadth and boundaries of a phenomenon but do not directly confront the original conclusion. In fields that have historically emphasized tests of generalizability, such as EBE, positive results can appear to establish the broad applicability of a phenomenon without ever actually testing its replicability – especially given the biases against publication of null results (reviewed in Fidler et al. 2017). Advancing theory in our discipline requires both testing predictions in new systems and assessing the validity of studies on which theory was built by attempting to replicate them (Cassey and Blackburn 2006, Fidler et al. 2017, Fraser et al. 2018).

## PROPOSED INNOVATION IN RESEARCH INFRASTRUCTURE

There have been prior efforts to assess the reproducibility of published analyses (i.e., 'computational reproducibility'; Archmiller et al. (2020); Kambouris et al. (2024)) or use statistical methods to infer confidence in the reproducibility of published studies (Yang et al. 2024). **We are proposing the first field-based effort to design and evaluate Replications as research method for EBE – The Reproducibility Project in Tropical Biology (RP-TB).** The ultimate goals of the RP-TB are (1) to determine the extent of reproducibility in a sample of the ecological literature, (2) to identify obstacles to conducting effective replications (e.g., a lack of methodological detail in the original study, the extinction of species or loss of study site, changes in environmental conditions, or advances in methods for sampling or analysis), (3) to quantify predictors of replication success (e.g., the location, ecosystem, or species with which the experiment was conducted, the extent to which the original study system has been altered by human activities), and (4) to identify aspects of experiments that are/are not critical to a successful replication (e.g., study species or location, specific characteristics of the sample, details regarding the materials or methods). *This proposal is the critical first step towards achieving these goals* because will provide the evidence and infrastructure needed to shift the current EBE research paradigm towards one in which Replication is a broadly accepted research method. **Our proposal has three objectives:**

1. **Objective 1: To develop the infrastructure for incentivizing, conducting, and publishing replications** of ecological field studies (Nakagawa and Parker 2015, Fidler et al. 2017), including **training** on the theory and practice of this research method,
2. **Objective 2: To provide evidence** of the potential for replications to advance scientific understanding (Fraser et al. 2020), and
3. **Objective 3: To assess community attitudes regarding replication in response to our novel research infrastructure**, especially the reasons for any continued hesitation to adopt replications *even if shown to be intellectually and professionally valuable.*

To successfully achieve these objectives we have brought together leaders from three stakeholders vital to the acceptance and implementations of Replications – universities, scholarly societies, and journals – along with pioneers in the Reproducibility movement and experts on the assessment and acceptance of academic innovations (Fig —).

## IMPACT ON THE RESEARCH COMMUNITY

*This section of the project description should address the biological user community impacted by the proposed effort and provide evidence of the need for the proposed innovation as compared to existing capabilities. Proposals should also explicitly state how the proposed work will advance the capabilities of the biological research community as it specifically relates to the research as*

*supported by the divisions within the NSF's Directorate for Biological Sciences.*

While the results of our project could have transformative effects on field-based disciplines beyond biologists, this proposal is focused on field-based biologists investigating questions in Ecology, Behavior, and Evolution (EBE). This biological user community is supported by several divisions in the Directorate for Biological Sciences (e.g., DEB, IOS, DBI, EF). The results of EBE research are critical for documenting threats to biodiversity, identifying priority areas for conservation, guiding the management of plants and animals harvested for human use, and informing policy at local, national, and international levels. These decisions rely in part on studies whose results may or may not be reproducible, however, which could have major - even catastrophic - consequences. For instance, one could overestimate the biodiversity in potential biological reserves based on snapshot surveys of bioindicator species (e.g., ants, understory plants, pollinators, frugivores/seed dispersers) whose results are anomalous. Alternatively relying on studies that have not been replicated could lead to conservation action that is too narrow in scope to be effective or distracts from more important conservation priorities. For example, climate change is expected to lead to the extinction of biodiversity on mountains as warm-climate species move up in elevation, but to date only one survey of biodiversity along elevational gradients has been replicated. This study suggested the impacts were even more severe than predicted; replicating other such studies will help determine if resources devoted to conservation are appropriate, overly conservative, or should be redirected to other priorities.

**Our project will advance the capabilities of the EBE community in four important ways. First,** there is the **new knowledge gained** by replicating the foundational studies. Are the results of these studies similar when replicated decades later and in new locations? If not, are the new results qualitatively similar, equivocal, or contradictory? Do we have to revisit alternative hypotheses and conduct new research in light of the replication results? In answering these questions, the participants in our project will make major conceptual advances: they will both test and refine classical theories and accelerate the development of novel ones.

**Second,** this initiative will drive **an important and positive change in scientific culture.** The impediments to replicating prior work are the same in field biology as they are in other disciplines - limited financial resources, skepticism regarding the extent of a 'reproducibility crisis', and a culture emphasizing novelty, often at the expense of rigor. We expect our results will demonstrate to this community of scholars why replication is essential, promote a vigorous discussion about the studies that are most urgent to replicate in light of the theoretical and applied impacts, and provide guidance for designing and describing studies that can be readily replicated. Our ambition is that tropical biology undergo a transformative change in scientific culture, with replication and reproducibility becoming integral components of rigorous research.

**Third, there will be tangible professional benefits for participating scientists.** In addition to funds for field research, at least two publications, and a new network of collaborators (*see Section —*), our initiative will also **train a cadre of early career scientists in methods to conduct reproducible and open science.** Students conducting reproducibility trials as part of their senior theses, in field courses, or as part of their graduate research will immerse themselves in our field's fundamental studies and conduct rigorous research and analyses under the mentorship of senior colleagues. This enhanced training and the resulting publications - which in most cases would likely not be possible without the financial support and incentive from this project - will accelerate their development as scientists and strengthen their professional network through international collaboration and engagement with the ATBC. It is also a critical element of transforming the culture of field biology - while more senior scientists are often resistant to the emerging culture of Open Science, Early

Career Scholars are more receptive to it, aware of its benefits, and eager to learn the requisite skills required to broadly share research protocols and results.

**Finally**, field-based sciences such as tropical biology face unique and inherent challenges to reproducibility from which many lab-based disciplines are buffered. This poses important philosophical questions about reproducibility, including fundamental ones such as what it means to ‘reproduce’ a study, if our goals should be replication or reproduction, and if replication is even possible. Our project is not the first to broach these questions, but it is the first in which they figure so prominently. **The resulting dialogue between teams within and across reproducibility initiatives will advance our understanding of science, its practice, and the consequences for science’s relationship to society.**

## PLANNED ACTIVITIES, MANAGEMENT, & EVALUATION

*This section should describe the planned activities, including the design of the proposed innovation, performance metrics, the biological research motivations for performance criteria, and how the design plan derives from these motivations. This section should also include a discussion of the expected results and a risk assessment with alternative approaches should the proposed favored approach fail. The development plan should contain sufficient detail to allow assessment of the feasibility of the innovation and the potential success of the project. Included in this section should be details of a timeline for assessing development objectives.*

### DESIGN OF THE PROPOSED INNOVATION

**Objective 1: Incentivizing, Conducting, and Publishing Replications:** In Year 1 we will solicit and select Principal Investigators (PIs) to guide the replication of five studies on our priority list. This list was generated by consulting a geographically and professionally diverse group of tropical biologists to identify studies they felt it would be valuable to replicate because of their key role in the conceptual development of the field or because of they informed key aspects of conservation and management. The list of studies was then narrowed to 15 that whose methods that are readily replicated with widely available, low-cost materials (*Table —*)

These PIs – with the assistance of the Center for Open Science, an ATBC Committee, and *Biotropica*’s Editors – would develop and post the guidelines for replicating a study, including the protocols, materials required for data collection, and scripts for data validation and statistical analyses to be used by participating researchers. The ATBC would then help PIs recruit a network of researchers in different locations to replicate the study.

Implementing a local replication requires working with the PI’s to pre-register the study (Chambers et al. 2014, Nosek and Lakens 2014) with *Biotropica*’s Editorial Board, which peer reviews the design and provisionally accepts a Registered Report for publication prior to any data collection. This model, which has been adopted by a number of journals participating in Reproducibility Projects (see <https://cos.io/rr>), both enhances the credibility of projects and provides incentive for participation because it guarantees publication of results regardless of statistical significance or magnitude of the effects (Chambers et al. 2014, Nosek and Lakens 2014). Moreover, this model facilitates engagement of experts in the design of the methodology and leads to consensus on what constitutes a replication test of a study before the results are known (Nosek and Errington 2020b). This is valuable both for improving the quality of replication designs and to address the potential for pre-existing beliefs to motivate accepting or dismissing a replication’s outcome. Once the data have been collected, the PI’s will work with the research teams to analyze and archive it and prepare the results-included Registered Report for submission to *Biotropica*.



## OUTCOMES ASSESMENT & PERFORMANCE METRICS

**Objective 2: Evidence of the potential for replications to advance scientific understanding:** When all of the replications have been completed, the PIs will conduct a meta-analysis of the entire network's results – also to be published in *Biotropica* – with all network members as co-authors. We anticipate these meta-analyses will be high-impact advances given the geographic scope, methodological consistency, and the conceptual importance to the field of the selected studies. That all participants would be authors or co-authors of two publications irrespective of their replication's outcome is a critical incentive we hope would encourage those who might otherwise be hesitant about repeating the work of others to participate.

**Objective 3 Assess the infrastructure and its community impact**

### OUTCOMES ASSESMENT:

*Identify what metrics will be used to measure success toward the stated goals of the project (both Intellectual Merit and Broader Impacts) and by what process the projects will collect and evaluate them.*

## PROJECT MANAGEMENT & KNOWLEDGE SHARING

### *Roles and Responsibilities of Key Personnel*

The Association for Tropical Biology and Conservation and COS are the ideal institutions to implement this initiative. With over 800 members in 65 countries, the ATBC is the largest and oldest academic society dedicated to the study and conservation of tropical ecosystems. The ATBC also publishes *Biotropica* – the leading source of original research on tropical ecosystems and the outlet for the reports resulting from replicated experiments. Its global membership and readership helps assure that our Reproducibility Initiative will be implemented in a diversity of ecosystems throughout the tropics. Throughout the process – from planning to workflow development to implementation – the COS will provide the administrative support and expertise gained through their Reproducibility Projects in Psychology and Cancer Biology.

*Include: means of communication and data management within the project team (integration of new team members)*

**Annual Milestones:** —

**Risk Assessment:** The primary risks for the project are (1) finding people to come on board as network PIs and Network Members (buy-in from the research community) and (2) convincing people of the value of replications. We hope that by leading two of the replications, and then incentivizing with stipends and research funds we will overcome this first challenge, and that results will leave towards transformative behavior.

## COMMUNICATION & KNOWLEDGE SHARING

*Describe how knowledge obtained through support of this work will be disseminated to its target audience and to the broader biological, interdisciplinary, and other audiences. When appropriate, describe how the products (instrumentation, software, research methods) of this work will be accessible to its target audience and to the broader biological, interdisciplinary, and other audiences. Provide a clear statement of relevant intellectual property considerations and any constraints these may place on access to the proposed resource.*



## INTELLECTUAL MERIT

Some of the most important advances in tropical biology have come from researchers forming networks to systematically collect observations, such as distributed experiments to study the effects of precipitation extremes on trophic structure (e.g., Romero et al. 2020) and permanent plot networks to study tree growth and diversity (Menke et al. 2012, Anderson-Teixeira et al. 2015, Poorter et al. 2016, Rovero and Ahumada 2017). The Reproducibility Project in Tropical Biology (RP:TB) we envision complements these efforts with a new means by which researchers throughout the tropics can collaborate to test and advance theory. The data from replications will also be highly valuable for quantifying the generality, impact, magnitude, speed, and consequences of human-induced alteration of ecosystems. Nowhere is this need more critical than in tropical ecosystems, which are home to majority of the world's biodiversity and human population, play a critical role in global climate, and are being transformed by humans at an unprecedented rate and scale.

## BROADER IMPACTS

Because many of the experiments proposed for replication are inexpensive to implement and monitor, and financial obstacles to individual participation will be eliminated when the RP:TB is finally funded, we expect this initiative will greatly expand the diversity of researchers participating in or leading networks. We especially hope the RP:TB will serve to stimulate much needed North-South and especially South-South collaboration (Stocks et al. 2008), thereby providing important opportunities for international collaboration to US-based faculty and students. The ATBC-organized workshops and symposia emerging from the project will also serve as an important tool for capacity building and the professional advancement of early career scientists, as will the integration of reproducibility projects and a culture of open science in field courses and other educational programs.

## RESULTS FROM PRIOR NSF RESEARCH

*When appropriate, this section must include evidence of deposition of samples, data and/or data products in recognized, accessible, community-accepted repositories by listing such repositories and, if practical, metadata. All publications, data, data products, programs and/or scripts that are specifically mentioned in the Results from Prior NSF Support section must be referenced in the References Cited section and must provide unique, resolvable and persistent identifiers (such as Digital Object Identifiers [DOIs]; Uniform Resource Locators (URLs), or similar).*

**Bruna:** “SG: Synergistic effects of forest fragmentation and droughts on tropical plant demography” (DEB-1948607, \$214,390). **Intellectual Merit:** The project had two objectives (1) to test for lagged effects of precipitation extremes on the vital rates of the Amazonian understory herb *Heliconia acuminata*, and (2) to build integral projection models (IPMs) with lagged effects to simulate the dynamics of populations in forest fragments and continuous forest under IPCC scenarios for the Central Amazon. Effects of precipitation extremes on vital rates could be delayed up to 36 months, with more pronounced effects on plants in fragments than on those in continuous forest. IPMs suggest that populations in fragments will decline under all IPCC scenarios, while the positive lagged effects of drought on growth will lead populations in forest to increase. The project resulted in two published articles, with two more in preparation, along with a permanently archived demographic dataset (>66,000 plant × year records of >8500 plants) and code repositories with a real-time data summary and validation dashboard and code for users test for lagged effects with their data sets. **Broader Impacts:** The award supported 1 Postdoc and 2 REU students. The students gained skills programming, statistics, and using quantitative methods to test ecological

hypotheses. The postdoc's programming lessons and archives were fundamental to his being hired as a Scientific Programmer & Educator at the U. of Arizona. The PI developed educational materials on climate change and tropical forests for a general education course and data management for a graduate course.

*Queenborough:*

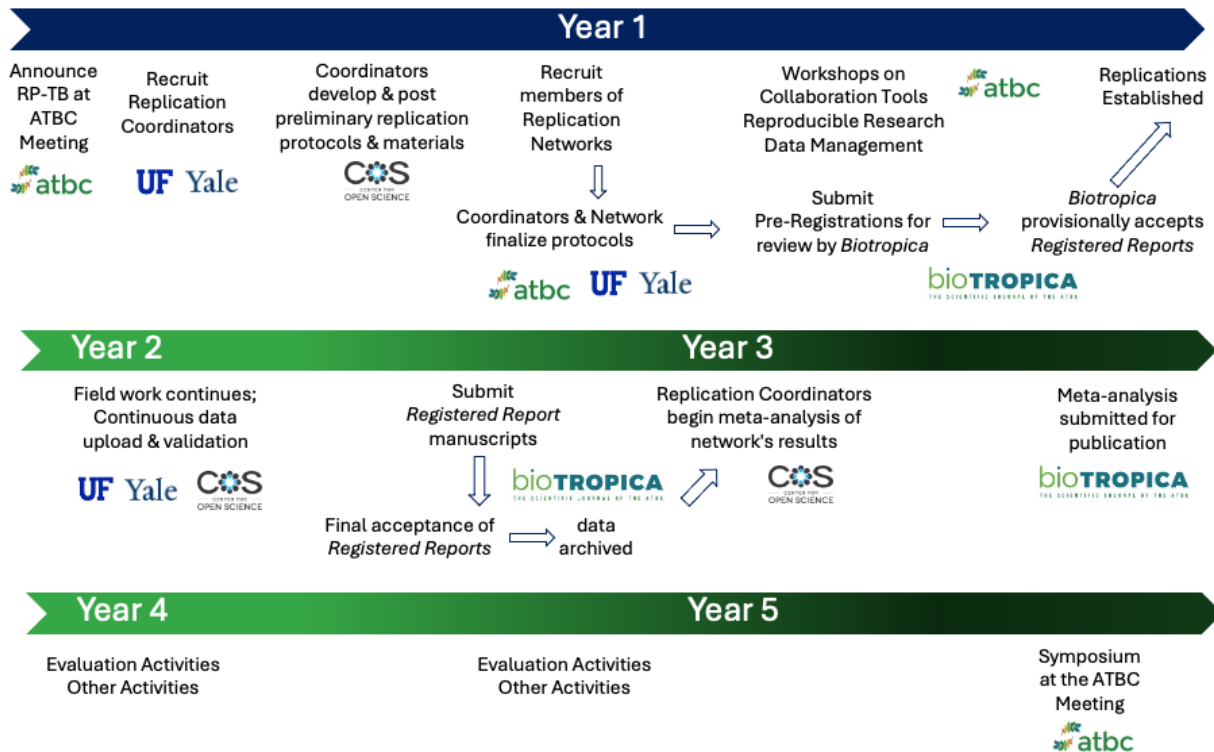




Figure 1: RP-TB Partner Organizations. **The Association for Tropical Biology and Conservation (ATBC)** is the largest and oldest professional organization dedicated to the study and conservation of tropical ecosystems. It's activities center on improving communication and cooperation among investigators, educators, environmental managers, and local communities, (2) the improvement, maintenance and accessibility of facilities, databases, and collections for tropical research, and (3) training the next generation of tropical scientists. The ATBC is international in scope and membership, its >1000 members are based in over 60 countries. *Biotropica* is the ATBC's international journal. Its diverse Editorial Board – over 40 members based in >20 countries – handles over 500 submissions per year. Over 40% of its articles have a student as lead author, and —% of it's lead authors are based in the Global South. It has lead the way with numerous innovations in EBE publishing to support its international author base, including foreign language abstracts, full support for author expenses without requiring waiver requests (e.g., Dryad fees, language editing, color figures are all *gratis*), and flexible embargo periods for the mandatory data archives. **The Center for Open Science (COS)** seeks to change the research culture and support open science behaviors to accelerate the pace of discovery. It will provides infrastructure to achieve open, reproducible science, and catalyzes communities to alter their norms, incentives, and policies to promote rigor. It has experience in community building around new norms, including the Reproducibility Initiatives in Psychology and Cancer Biology and the implementation of Pre-Registrations. The **University of Florida (UF)** has the TCD program and Yale University has cool stuff too.

Table 1: Examples of replications vs. generalizability tests with tropical systems. Note that replications in EBE have often been characterized by how closely the species and location matched those of the original study (e.g., 'direct', 'partial', or 'conceptual' replication; reviewed in Kelly (2006), Nakagawa and Parker (2015), Fidler et al. (2017)). However, we use the more conceptually generative definition of a replication: A study for which any outcome is diagnostic evidence of about a claim from prior research (Nosek and Errington 2020b).

Potential replications			Generalizability Tests
Approach 1	Approach 2	Approach 3	Approach
Duplicates original methods with same species or populations in original location	Duplicates original methods using same species or populations but in different location	Duplicates original methods but in different species or systems	Tests of same hypothesis with new methods
<b>Examples using Janzen (1967)</b>			
Removal of <i>Pseudomyrmex ferruginea</i> from <i>Vachellia cornigera</i> (formerly <i>Acacia</i> ) in Guanacaste National Park in Costa Rica.	Removal of <i>P. ferruginea</i> from <i>V. cornigera</i> in Southern Mexico using original methods	(a) Removal of <i>P. ferruginea</i> from <i>V. collinsii</i> using original methods, <b>or</b> (b) Removal of <i>Crematogaster laevis</i> ants from <i>Tococa bullifera</i> using methods based on the original study	Comparing herbivory on plants after manipulating ant access to extrafloral nectaries.
<b>Examples using Dirzo et al. (1992)</b>			
Sample herb communities in gaps of different sizes and ages in the lowland forests of Los Tuxtlas, Mexico.	Sample herb communities in gaps of different sizes and ages in the lowland forests of the Maya Biosphere Reserve, Guatemala.	(a) Sample herb communities in gaps of different sizes and ages in lowland forests of Borneo or Brazil using original methods, <b>or</b> (b) Sample herb communities in gaps of different sizes and ages in dry forests or cloud forests	(a) Sample tree communities in gaps of different sizes and ages, <b>or</b> (b) Sample herb communities on landslides of different ages or sizes.

Table 2: Studies proposed for replication. Replicating these studies would both advance biological theory and inform - directly or indirectly - the conservation or management of tropical biodiversity and ecosystem services.

Article	Justification
<b>Interspecific Interactions and Population Dynamics</b>	
Coley 1983	Demonstrated plant characteristics interact with local environmental conditions to influence the plant defensive chemistry central to plant-herbivore coevolution; replicating it in other locations will help refine ecological models of community coexistence and plant evolutionary theory.
Augsburger 1983	Demonstrated fungal pathogens were an important and underappreciated mechanism influencing seedling establishment. However, we still know little about large-scale variation in pathogen effects or how climate change has altered them, even for species central to conservation (e.g., mahogany, Brazil nut). Replicating this study fill this data void.
Janzen 1967	The >300 species of tropical plants that house ants in specialized structures (e.g., hollow thorns, leaf-pouches) have fascinated naturalists since the 1600s. This experiment was the 1st to unequivocally show that ants defend their host-plant from herbivores, but perhaps its greatest impact was demonstrating that ant-plant systems are exceptional ones for experimental investigations of how mutualisms shape ecological communities. Replicating this study will provide one of the most comprehensive examples of how and why mutualisms and their impact vary geographically.
Marquis 1984	Was one of the first to show that herbivory leads to reduced seed production by plants; as a result, subsequent studies modeling the long-term viability of plant species often attempt to incorporate direct or indirect measurements of herbivory's impact. Replication will help assess under what circumstances these labor-intensive and challenging measurements are actually necessary.
<b>Tropical Environments and Organismal Responses to Environmental Conditions</b>	
Chazdon and Fetcher 1984, Kitajima 1984	The limited sunlight reaching the understory of tropical forests (< 2%) limits plant growth and survivorship. These fundamental studies mapped understory light levels and documented how plants respond physiologically to variation in the light environment. Replicating them across gradients of forest disturbance will elucidate how plants respond to the changes in forest structure and microclimate resulting from deforestation and other human activities.
Ewel 1976	40% of tropical forests are "successional" forest regenerating in areas abandoned after deforestation. How these areas were used prior to being abandoned strongly influences nutrient cycling in regenerating forests, which in turn influences species diversity and carbon sequestration. Global replication will provide the most robust data to date on these questions, informing the principal policy mechanisms promoting forest conservation.
<b>Species Diversity and Dynamics</b>	
Denslow 1980, Ryan et al 1983, Gentry and Dobson 1987, Jankowski et al 2009	Fundamental in describing how 1000s of species are able to coexist in tropical ecosystems when competing for the same resources. Revisiting their conclusions is essential in light of the myriad ways tropical ecosystems are being altered, since most conservation policies are based on the original results.
<b>Anthropogenic Impacts on Tropical Systems</b>	
Bruna 1999, Holl 1999, Carvalho & Vasconcelos 1999, Menke et al. 2012	Have provided some of the most widely cited insights on plants and animals that persist in habitat fragments following deforestation. Replication - especially in the understudied forests of equatorial Africa - will help ensure that the results are truly applicable to other regions or if resources are better allocated to studying other species and processes.

## References

- Amaral, O. B., K. Neves, A. P. Wasilewska-Sampaio, and C. F. D. Carneiro. 2019. The brazilian reproducibility initiative. *eLife* 8: e41602.
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