TBD for Reproducibility Grant

A. 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)

B. 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*)?

C. 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

D. 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?

E. Financial

1. PI Salary Support: EB, SC, Assessment PI, BN?
2. Postdocs or GAs
3. Replication Grants (as subcontract to ATBC)
4. ATBC Overhead
    - bank fees
    - stipends for Editor and Treasurer for additional work
    - stipends to incentivize Replication Leaders

5. Travel to Meetings & Workshop Materials
6. 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 field-based studies.* We will do so by supporting, coordinating, and evaluating the replication of (five?) fundamental field-based 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). 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).

To be clear, there is no such thing as exact replication, regardless of discipline and research context. There will always 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

Shifting the current EBE research paradigm towards one in which Replication is a broadly adopted method will require an innovative infrastructure for (1) incentivizing, conducting, and publishing replications (Nakagawa and Parker 2015, Fidler et al. 2017). It will also require **(2) training** on the theory and practice of this method, **(3) evidence** of the potential for replications to advance scientific understanding (Fraser et al. 2020), and **(4) an assessment of community response**, including potential barriers to adopting replication *even if shown to be intellectually and professionally valuable*.

We are proposing to develop, test, and assess this infrastructure by coordinating the Reproducibility Project in Tropical Biology -– the first such effort in environmental biology. **The Project has five primary objectives:**

1. To determine the extent of reproducibility in a sample of the fundamental literature in Tropical Biology
2. To identify obstacles to conducting effective replications, including such factors as failure to detail methodology in the original study, the extinction of species or loss of study site, changes in local, landscape, or global environmental conditions, advances in sampling technology, statistics and computational tools, analytical methods, etc.
3. To quantify predictors of replication success, such the location, ecosystem, and species with which the experiment was conducted and the extent to which the original study site and system has been modified by human activities
4. To identify aspects of the experiment that are/are not critical to a successful replication, such as study species or location, specific characteristics of the sample, or details of the materials and methods.
5. To advance the training of early-career scientists and collaboration among tropical biologists, especially the training of students in developing countries, North-South and South-South collaborations, and collaborations between Early-Career and Senior Scientists through conducting replications and training of researchers in open and reproducible research methods at societal meetings.

To address these obbjectives we have assembled a team that brings together leaders from the different stakholders fundamental to the intitiave's success: researchers, a scholarly society that supports international research and capacity building, a leading disciplinary journal with a history of innovation, and experts in the implementation of reproducibility initiatives.

IMPACT ON THE RESEARCH COMMUNITY

TO DO: *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.*

Biological User Community

Our project will have four major impacts on the science and scientific culture of the research community. **First**, there is the ***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 ***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, our initiative will have a ***global impact on the training of students and early career scientists***. 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 tropical 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***.

PROJECT IMPLEMENTATION, MANAGEMENT, & EVALUATION

IMPLEMENTATION OF THE RP-TB: Below we describe the activities for building and assessing the infrastructure for implementing and testing Reproducibility as a Research Method:

(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. 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*.

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.

(2) Training

(3) Evidence of the potential for replications to advance scientific understanding

(4) Assessment Community Response

PROJECT MANAGEMENT:

Roles and Responsibilities of Key Personnel

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

Annual Milestones

Risk Assessment

COMMUNICATION & DISSEMINATION

TODO: *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.*

OUTCOMES ASSESMENT:

TODO: *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.*

INTELLECTUAL MERIT

1 paragraph

BROADER IMPACTS

Some of the most important advances in tropical biology have come from researchers forming networks to systematically collect observations of tree growth and diversity in permanent plots (Menke et al. 2012, Anderson-Teixeira et al. 2015, Poorter et al. 2016, Rovero and Ahumada 2017). The same is likely to be true as tropical biologists embrace "distributed experiments" (Fraser et al. 2013, Borer et al. 2014), in which the same experimental manipulation is implemented at geographically and ecologically disparate locations (e.g., Romero et al. 2020). 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. 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. Finally, the data from replications will 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.

It is essential to emphasize that this reproducibility project will have societal impacts that extend beyond the transformative effects on field-based disciplines. The research conducted by tropical biologists is 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.

In sum, there are few areas with greater policy implications in the 21st century than research on ecology, biodiversity conservation, deforestation, and climate change. Government policies addressing these issues have local, national, and international consequences, with economic, social, and cultural impacts. It is therefore essential that tropical biologists provide the policy-makers whose decisions will affect the health and well-being of the planet and its citizens with the most robust and reliable evidence available.

RESULTS FROM PRIOR NSF RESEARCH

TODO: *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:

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
Examples using Janzen (1967)			
Removal of *Pseudomyrmex ferruginea* from *Vachellia cornigera* (formerly *Acacia*) in Guanacaste National Park in Costa Rica.	Removal of *P. ferruginea* from *V. cornigera* in Southern Mexico using original methods	**(a)** Removal of *P. ferruginea* from *V. collinsii* using original methods, **or** **(b)** Removal of *Crematogaster laevis* ants from *Tococa bullifera* using methods based on the original study	Comparing herbivory on plants after manipulating ant access to extrafloral nectaries.
Examples using Dirzo et al. (1992)			
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, **or** **(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, **or** **(b)** Sample herb communities on landslides of different ages or sizes.

Table 2: List of proposed articles and justification (needs formatting)

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