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COMMENTARY

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Looking to the past to understand the future of tropical conservation: The importance of collecting basic data

50 YEARS OF biotropica 1969-2019

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Abstract

Tropical biodiversity is under threat from a wide variety of anthropogenic stressors. Understanding the effect of major stressors—most notably land use change, overharvesting, emergence of novel pathogens, and climate change—is a major goal of tropical biology. However, to do so requires baseline data with which to compare present-day patterns. Unfortunately, the tropics suffer from a lack of basic historical data; the few studies which have published such data have proven invaluable. In 1989, Fauth et al. described their studies of reptile and amphibian diversity and population demographics across tropical elevational gradients in Costa Rica. Since then, Fauth et al.'s basic ecological data have been widely used to document shifting patterns of species composition and abundance. Here, 30 years later, we argue that (a) collecting foundational ecological data remains incredibly important, especially in the tropics, and especially in those taxa which are generally understudied (e.g., reptiles and amphibians), (b) despite being one of the original goals of the 1989 study, the mechanisms driving biogeographical patterns of diversity remain unclear (both in the tropics and globally), and (c) that revisiting sites of historic biodiversity surveys—particularly those along gradients of environmental change—is incredibly important to our understanding of how tropical diversity is currently, and will continue to be, affected by activities in the Anthropocene. In its simplest terms, there has never been a time where the collection of basic data in the tropics has ever been more important.

KEYWORDS
amphibian, basic data, conservation, reptile, tropical biology

1 | INTRODUCTION

It is widely hypothesized that tropical species and ecosystems will be at a greater overall risk from both short- and long-term global stressors than species in non-tropical (i.e., temperate) regions (Laurance, 2007; Stroud & Feeley, 2015). Immediate threats include habitat loss, alteration, and fragmentation, the rates of which are highest in the tropics relative to other areas, and—in tandem with the emergence of novel infectious diseases—constitute the greatest short-term threats to tropical biodiversity and ecosystems (Brook, Sodhi & Bradshaw, 2008; Wake & Vredenburg, 2008). Similarly, those species under threat from poaching for medicine and the bushmeat trade are heavily skewed toward the tropics (Milner-Gulland & Bennett, 2003). Under long-term global stressors, such as climate change, tropical species are also considered under elevated risk relative to non-tropical species due to relatively higher thermal specialization (Janzen, 1967; Perez, Stroud & Feeley, 2016). Despite this, the tropics remain understudied and overlooked in almost all subdisciplines of ecology and evolution (Stroud & Feeley, 2017).

In an effort to overcome this bias in knowledge, it is important that we better understand the fundamental processes and patterns underlying tropical ecosystems. Accurately understanding how global change is affecting tropical biodiversity requires baseline data with which to compare current patterns; basic ecology is fundamental to conservation. Unfortunately, for many tropical species, these types of foundational data often do not exist, and if they do, data are often sparse or patchy (Collen, Ram, Zamin & Mcrae, 2008; Feeley & Silman, 2011a,b). Here, as we look toward "*The Next 50 Years*," we describe how the impact of a single case study in *Biotropica*, which set out to document basic ecological data—species distributions, abundances, and compositions of reptiles and amphibians at several tropical locations in a single country, has been important in developing our understanding of the fate of tropical species all over the world in the Anthropocene.

2 | A CASE STUDY: COSTA RICAN REPTILES AND AMPHIBIANS

In 1985, John Fauth, Brian Crother, and the late Joe Slowinski conducted field surveys of reptile and amphibian species along an elevational range in Costa Rica (Fauth, Crother & Slowinski, 1989). The sites were chosen to represent a gradient of tropical habitats from lowland rain forest (Tortuguero, Heredia Province), through dry forest (3m; Palo Verde)), moist rain forest (100m; Las Vegas, La Selva Biological Reserve), primary rain forest (650-1120m; Braulio Carrillo National Park), and premontane rain forest (1050m; Monteverde, Alajuela Province), before finally reaching a summit of montane wet forest (1640–1670m). By today's publishing standards, the authors' results may be considered unremarkable; "*A strong positive correlation existed between species richness and herpetofaunal density… Tropical leaf-litter reptiles and amphibians appear to be both more diverse and more abundant at lower elevations. Sites with deep leaf litter generally sustain dense and diverse reptile and amphibian populations. Local herpetofaunas typically consist of a few very common species along with a large number of comparatively rare species*." However, while we now may take a lot of these patterns for granted, the subsequent impact of this paper has been great. As of January 2019, Fauth et al. have been cited 150 times, attracting interest from studies distributed all over the globe (Figure 1), across many taxa (Figure 2), and across many topics (e.g., behavior, methods, systematics, and general ecology). Of these studies, over half have continued to develop our understanding of general patterns of tropical community ecology, while a quarter investigates patterns of biodiversity along elevational gradients, studies which were uncommon in 1989 and remain fairly uncommon to this day. In a recent meta-analysis of elevational range patterns of reptile communities—*from studies anywhere in the world*—only 65 data sets existed (McCain, 2010; compared to ca. 200 for birds, McCain, 2009). Prior to 1989, only six published studies of elevational patterns of reptile biodiversity from the tropics existed, the majority of which were limited to species accounts without any formal survey information.

2.1 | The importance of basic data to tropical conservation

The success of understanding how past conservation threats have affected biodiversity, as well as and forecasting how current threats will influence future patterns of biodiversity, relies fundamentally on the quality of baseline data. As new records of dramatic declines of

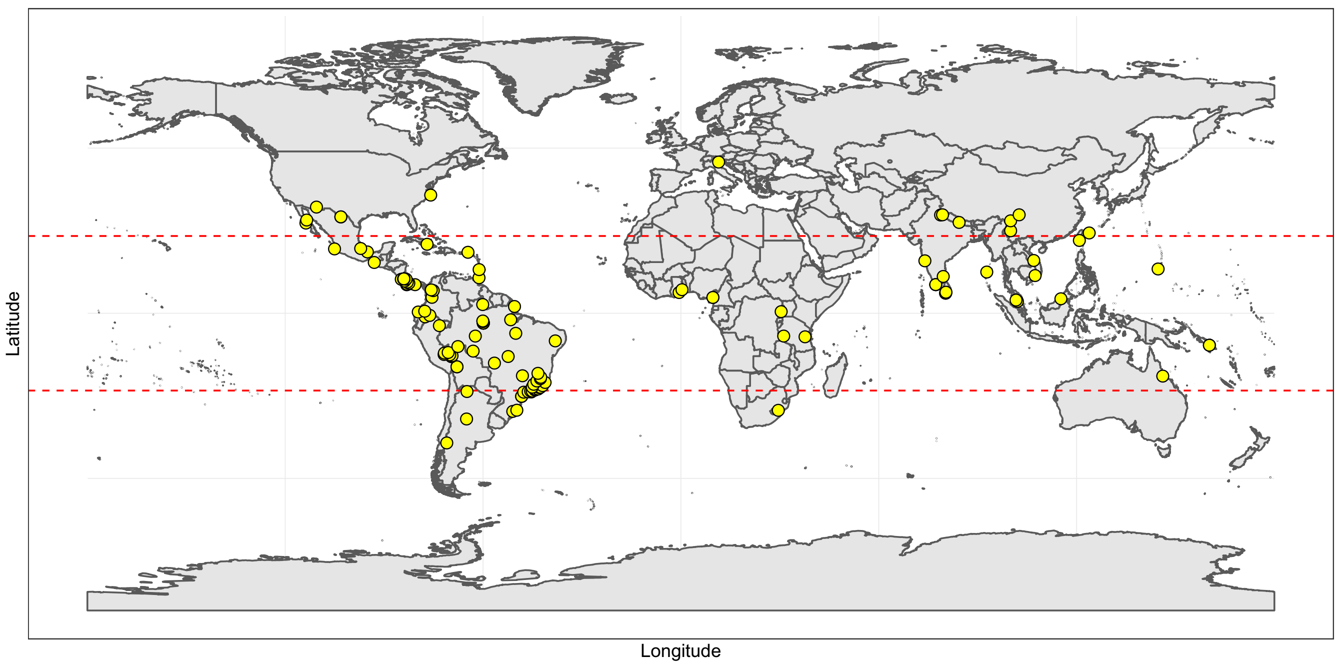

FIGURE 1 While most studies which have cited Fauth et al. (1989; yellow circles) are based in the tropics, the influence of the study has been far-reaching, often spanning beyond the tropics (±23.4° North and South of the equator; dashed red lines). All data from this literature review are available in Table S1

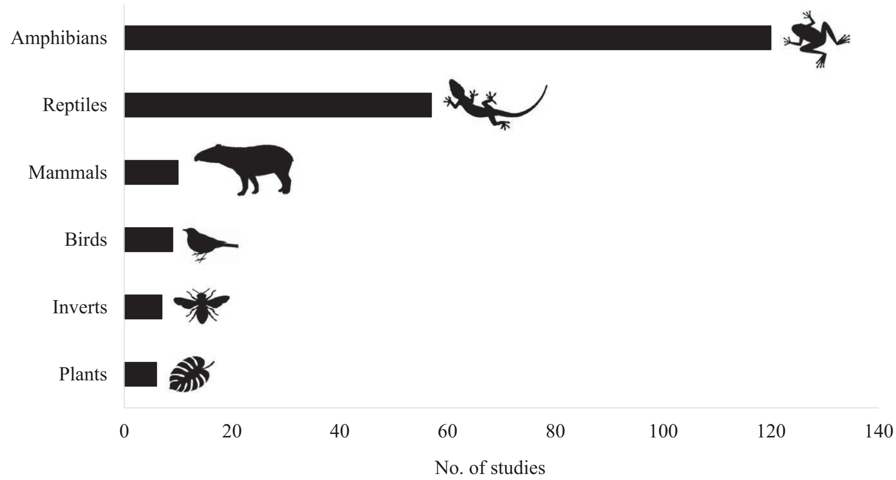

FIGURE 2 Exploring the taxonomic focus of studies which have cited Fauth et al. (1989) in the three decades since its publication. All data from this literature review are available in Table S1

reptile and amphibian populations across the tropics continues to mount, the value of studies like Fauth et al. in providing baseline data increasingly becomes apparent, "*we require intensive biotic surveys of amphibians along elevational and latitudinal transects to describe the geographic distribution of the problem, identify potential causes, and prioritize conservation efforts*" (Lips, Burrowes, Mendelson & Parra-Olea, 2005). Empirical data of species distributions and abundances from Fauth et al. were pivotal in demonstrating widespread reptile and amphibian declines in Costa Rica in the 35 years subsequent to those original surveys (Whitfield et al., 2007). Since then, an explosive revelation of similar patterns elsewhere in the global tropics has been identified, which have been critical in identifying taxa and regions of high conservation risk (Moritz & Agudo, 2013; Wake & Vredenburg, 2008).

3 | UNDERSTANDING BIOGEOGRAPHIC PATTERNS REMAINS A CHALLENGE

> Before attempting to determine the mechanisms responsible for observed patterns of tropical leaf-litter abundance and diversity, we must document the phenomenon conclusively. Fauth et al. (1989)

One of the original goals of Fauth et al. was to understand patterns of species distributions and range limits in the tropics. Identifying the mechanisms which determine range limits was, and remains, a major goal in ecology and evolution (Sexton, Mcintyre, Angert & Rice, 2009). However, despite decades of research, our understanding of the factors which determine species ranges, especially in the tropics, remains relatively poor (Brown, Stevens & Kaufman, 1996; Gaston, 2003; Pigot, Owens & Orme, 2010). For example, as outlined by Fauth et al., 1989, "*It has become generally accepted that leaf-litter reptiles and amphibians are more abundant in the New World Tropics than in Southeast Asia although the exact reason remains a subject of debate (May, 1980).*" Three decades on, there remains no consensus on why the New World Tropics promote such a diverse assemblage of leaf litter herpetofauna relative to the Asian tropics; a comparative analysis originally spearheaded in *Biotropica* (Scott, 1976). Large knowledge gaps remain about what determines species ranges in the tropics and therefore why tropical biodiversity is unevenly distributed. Understanding the abiotic and biotic mechanisms underlying biogeographic patterns remains a primary objective of tropical biology.

4 | BASIC DATA, THE TROPICS, AND ANTHROPOGENIC STRESSORS

The flora and fauna of the tropics are facing a plethora of anthropogenically driven threats. Of those taxa in the tropics, reptiles and amphibians face one of the most uncertain futures (Alroy, 2015). What are the major stressors affecting tropical reptiles and amphibians, and how are they expected to respond?

4.1 | Habitat loss and change

Habitat loss and degradation are listed as a main threat to 85% of all species on the IUCN Red List (IUCN 2015). Tropical regions are undergoing particularly high rates of forest loss driven primarily by industrialized, large-scale agriculture, natural resource extraction, and an accompanying proliferation of roads (Laurance, Sayer & Cassman, 2014; Wright, 2010). Typically, habitat alteration has a negative effect on species richness of tropical amphibians and reptiles (Gardner, Barlow & Peres, 2007; Gillespie et al., 2015). However, species-specific responses are highly variable and context-dependent on the type and magnitude of habitat alteration as well as evolutionary history of lineage (Gardner et al., 2007; Kolbe et al., 2016; Nowakowski, Frishkoff, Thompson, Smith & Todd, 2018; Thompson, Nowakowski & Donnelly, 2016). Understanding the complexities of how amphibians and reptiles respond to habitat alteration remains a formidable challenge. The ability to mitigate the negative impacts of habitat loss and degradation, accurately predict how species will respond to change, and develop effective land management and conservation strategies depends on continued fieldwork using standardized methods to collect basic data on populations, communities, and associated environmental characteristics.

4.2 | Novel infectious diseases

The first collective realization of alarming global trends in amphibian declines occurred in 1989 at the First World Congress of Herpetology. However, for many years, it was unclear whether these declines represented responses to novel stressors or constituted normal population fluctuations (Lips, 1998; Pechmann & Wilbur, 1994; Pechmann et al., 1991). It was suspected that a number of these reported declines were the result of a novel pathogen and it is now confirmed that the fungal pathogen *Batrachochytrium dendrobatidis* (*Bd*) is responsible for one of the largest known wildlife pandemics, infecting over 500 amphibian species, mostly Anurans (frogs and toads; Lips et al., 2006; Skerratt et al., 2007; Vredenburg, Knapp, Tunstall & Briggs, 2010; Olson et al., 2013). The recent emergence of a similar pathogen widely thought to specifically target Caudates (newts and salamanders), *B. salamandrivorans* (*Bsal*), threatens to pose similar issues (Yap, Nguyen, Serr, Shepack & Vredenburg, 2017). Lack of long-term data and natural history information on amphibians slowed the advancement of the understanding of the distribution of *Bd* and its contribution to amphibian declines (Laurance, Mcdonald & Speare, 1996; Lips et al., 2005). Museum specimens, archived data, and continued field inventories that incorporate sampling for *Bd* are critical to understand and quantify the impact of this pathogen on amphibians (Lips et al., 2005). And these threats are not just constrained to amphibians; ongoing reports of snake fungal disease (SFD) in nature, caused by the fungal pathogen *Ophidiomyces ophidiodiicola*, have been identified as an emerging threat to reptiles. Although currently linked to fatal skin infections in snakes in temperate regions, research suggests that this pathogen has a broad host range and represents a potential global threat (Burbrink, Lorch & Lips, 2017; Lorch et al., 2016). It is integral that we use the knowledge gained from *Bd* to mitigate similar patterns, although with a dearth of foundational data for many reptiles it is possible that some species may be driven extinct before it is even realized.

4.3 | Climate change

Global climate change is widely recognized as one of the most serious threats to global biodiversity. The tropics are predicted to experience a relatively larger and faster divergence from historic climates relative to temperate zones (Williams, Jackson & Kutzbach, 2007). This is especially bad news for tropical species, particularly those in lowland tropical rain forests which support the highest proportion of tropical biodiversity, as many have a high degree of thermal specialization resulting from long-term climatic stasis (Janzen, 1967; Terborgh, 1973). In response to changes in climate, there are four widely recognized responses for any species, including those in the tropics; (1) phenotypic plasticity may allow individuals to acclimate to novel climates (Stillman, 2003), (2) species may adapt to climate change, in other words through changes in genetic composition1 (Hoffmann & Sgrò, 2011), (3) species may track preferred climatic conditions through changes in their distributions (i.e., "migrations"; Feeley et al., 2011; Freeman, Lee-Yaw, Sunday & Hargreaves, 2018a), or (4) if none of these responses occur, a species will go extinct. In the absence of acclimation or adaptation, both considered theoretically unlikely in many tropical species (Ghalambor, Huey, Marti, Tewksbury & Wang, 2006), species migrations represent the most viable avenue for avoiding extinction. However, unlike their temperate counterparts, tropical species lack a latitudinal gradient in climate on which to migrate. Instead, tropical species are restricted to migrate along elevational gradients, for example, through upslope range shifts (Lenoir & Svenning, 2015). Whether this represents a viably sustainable response to climate change or merely delays extinction remains unclear (i.e., an "*escalator to extinction*"; Freeman, Scholer, RUIZ-Gutierrez & Fitzpatrick, 2018b).

[1]It is possible that phenotypic plasticity may itself lead to adaptive evolution, a theory first put forward by Baldwin (1896) and subsequently broadly disregarded, but one which has recently started to attract contemporary support (Futuyma, 2017; Levis & Pfennig, 2016).

5 | LOOKING FORWARD

It is now fairly common for many journals to require that data involved in current studies are archived and accessible in tandem with publication. This approach and transparency in ecological studies have revolutionized data accessibility over the past 10–15 years. Archiving current data, however, is fundamentally different from archiving *old data*, which may or may not have ever been used in publications. It is critical that tropical biologists are aware of the incentives of archiving old data; if unused, information degrades through time until it is eventually forgotten (Michener, Brunt, Helly, Kirchner & Stafford, 1997). In our efforts to both (a) increase our understanding of tropical ecosystems, and (b) understand how contemporary stressors are affecting tropical species, it is important to outline a few simple things that can help.

5.1 | Keep collecting

As we have discussed, any attempts to understand how current day patterns of biodiversity may have changed through time rely on historic data to provide a baseline. It is never too late to start collecting simple, structured data. Approaches like this may be particularly suited for those institutions which host annual (or biannual) tropical courses/workshops. For example, field biology courses led by the Organization for Tropical Studies (OTS) provide opportunities to collect and archive such data, as well as introduce students to the importance of standardized field sampling techniques, even across different tropical habitats. Data collected from OTS courses were essential in documenting dramatic amphibian and reptile declines in Costa Rican rain forest (Whitfield et al., 2007) and highlighting population declines of salamanders in Costa Rican páramo grasslands (Lips & Donnelly, 2005). It is integral that demographic field data are collected under standardized methods; many of which are well documented and freely available, to allow consistent comparisons across space and time (Heyer, Donnelly, Mcdiarmid, Hayek & Foster, 1994). Further collections will not only help to record changes in species ranges, abundances, or compositions, but can also be invaluable in validating modeling methods reliant on such records (Feeley & Silman, 2011a).

5.2 | Archive old data

If you have old data files, field notebooks, data sheets, or even organismal photographs from the field, please archive these data and make them publicly available! A gold mine of past data is undoubtedly hidden away in the drawers and hard drives of many tropical ecologists. There are several guides which provide information on how to archive data, for example, Michener et al. (1997), Bruna (2010), and White et al. (2013), as well as attempts to provide standardization of data terms across ecological studies (Schneider et al., 2018). Commonly used data repositories include; (i) *species occurrences*: the Global Biodiversity Information Facility (GBIF; www.gbif.org), VertNet (www.vertnet.org/), and iNaturalist (www.inaturalist.com), (ii) *general data*: Dryad (www.datadryad.org), NERC data center (www.nerc.ac.uk/research/sites/data), and Ecological Society of America's ecological data archive (http://esapubs.org/archive/). All of these archives have public access, and so, the data are freely available to other ecologists and tropical biologists.

5.3 | Revisit historic surveys

Finally, revisiting historic surveys can provide the most direct understanding of demographic, distributional, and compositional changes in tropical communities. Recent research which revisits baseline surveys suggest that some tropical ecosystems are already collapsing; in roughly four decades, *Anolis* lizard abundance dropped 23–78% in Costa Rica (La Selva), 71% in Panama (Barro Colorado), and 32% in Puerto Rico (Luquillo) (Lister & Garcia, 2018; Pounds, Fogden & Campbell, 1999; Stapley, Garcia & Andrews, 2015; Whitfield et al., 2007). Now is the time for tropical ecologists to dig into the archives, re-discover past survey data, and re-census tropical ecosystems. A word of warning, however, information from historical surveys can often be lacking in detail. If so, tropical biologists might instead be better informed to invest in establishing new, clearly defined transects that will pay dividends into the future, rather than imperfectly revisiting historic sites and potentially drawing false conclusions.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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