



The state of European research in tropical biology

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ABSTRACT

Research institutions from the Global North have made significant contributions to the knowledge of tropical ecosystems, but contributions have varied greatly between countries. We show that European nations that share a language, cultural affinity, and/or retain social and political ties with tropical countries (*e.g.*, those with an overseas history) make larger contributions to tropical biological research than countries without these ties. However, exceptions to this pattern demonstrate how science policy agendas can skew the capacity of countries to conduct biological research in the tropics. We conclude that some countries could make a far more important contribution to tropical biological knowledge, but for this to materialize, greater commitment by a country's scientific community is needed, along with better financial and intellectual support from its public administrations.

Abstract in Spanish is available with online material.

Key words: financial support; publication leadership; research policy; scientific productivity.

EVEN BEFORE THE EARLY EXPLORATIONS OF THE 18th CENTURY, NATURALISTS HAVE BEEN ENTHRALLED BY THE TROPICS. Such fascination arose mostly from the rich and diverse flora and fauna of tropical regions, unparalleled anywhere else on Earth (Kricher 2011). The extraordinary complexity and species richness of tropical ecosystems have inspired scientists to formulate new evolutionary and ecological paradigms (von Humboldt & Berg 1854; Bates 1864; Wallace 1869; 1870; Janzen 1983; Hubbell 2001; for a review, see Chazdon & Whitmore 2002), and still today tropical systems are a major driver of scientific research (Bawa *et al.* 2004; Zuk 2016).

The study of the natural history of tropical regions began to gain academic recognition during the age of global exploration, following a period of European economic expansion, colonialism, and mercantilism known as the “Commercial Revolution” (Lopez 1976). Emerging European states rushed in search of alternative trade routes in the 15th and 16th centuries, which allowed the European powers to build vast transcontinental trade networks (Morris 2010). In this context of economic expansion and trade during the 18th and 19th centuries, tropical biology became a recognized biological science. Naturalists, including Alexander von Humboldt, Jacques Bonpland, Charles Darwin, Alfred R. Wallace, and Ernst Haeckel, and before them James Cook, José Mutis, Hipólito Ruiz, Antonio Pavón, Martín Sessé, José Mociño, and Alejandro Malaspina, among others, explored tropical regions, mostly under the auspices of their respective governments. Anecdotally, there is also a long history of local research in tropical countries during their respective colonial periods. For

example, in 1818, while the Portuguese crown was in exile in Brazil, Dom Joao VI founded Brazil's Museu Real (today's National Museum), which acquired many of its specimens from the first natural history museum in Brazil, the ‘Casa dos Pássaros’, founded by Viceroy Dom Luis de Vasconcelos four decades earlier (Pires-O'Brien 2010).

The interest in tropical biomes entered the scientific mainstream of European academic institutions by the second half of the 20th century. Tropical research blossomed in part with the support of newly established professional societies with a specific focus on tropical research (*e.g.*, The International Society for Tropical Ecology, founded in 1960; or the Association for Tropical Biology and Conservation, founded in 1963), the creation of tropical field stations (*e.g.*, Barro Colorado Island Research Field Stations, established in 1946), and the rise of scientific journals devoted specifically to tropical biology (*e.g.*, *Biotropica*, first published in 1969; Kricher 2011). Ever since, institutions of the ‘Global North’ (a group of economically developed countries that collectively control most global wealth; Brandt 1980) have contributed to the growth of scientific knowledge of tropical ecosystems (Stocks *et al.* 2008; Malhado *et al.* 2014). Although the research capacities of some tropical nations have increased dramatically in recent decades (*e.g.*, Brazil or Mexico in the Americas; Malhado *et al.* 2014), wealthier western nations with long academic histories contribute disproportionately to tropical biology research (Holmgren & Schnitzer 2004; Stocks *et al.* 2008). Research contributions, however, vary significantly among wealthy countries. This is in part a result of scientific policy agendas (Malhado *et al.* 2014), and also geopolitical factors, history, language, and cultural traditions (Luukkonen *et al.* 1992). Western countries

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that share a language, cultural affinity and/or retain social and political ties with tropical countries—often the result of historical colonialism or transcontinental trade—are more likely to conduct biological research in the tropics (or are more successful at it). For example, there is evidence that a common language and culture influence the tendency of western countries to collect specimens from a given tropical country (Stropp *et al.* 2016). Given these historical and cultural precedents, it is natural to expect that western countries would engage more actively in the study of tropical systems for which they have social ties.

This paper aims to analyze the contributions of individual European nations to tropical biological knowledge (measured as the number of scientific publications) in relation to their research capacity (measured as the number of researchers in higher education institutions) and history of colonization, exploration, and trade throughout tropical regions. We test the central hypothesis that, all else being equal, European nations sharing historical links with tropical nations such as France, the Netherlands, Portugal, Spain, or the United Kingdom, contribute a larger share to tropical knowledge than nations with no such history. Overall, we expect that this study may be used to guide the agenda of European research institutions for support of tropical biology research. We also wish to promote research by western countries which, like Spain or Portugal, have not only a historical legacy but also great opportunities to conduct biological research in the tropics due to cultural and linguistic commonalities.

METHODS

To obtain an estimate of the overall scientific production in tropical biology in European countries, we used Thomson Reuters ISI Web of Science (accessed on 26 September 2016) to identify all publications containing the text string “Tropic*” in the fields “Topic”, “Title” or “Publication name”, for years 1975 to 2015. The results were refined to include only those articles within the domain ‘Science and Technology’ and research area ‘Environmental Sciences and Ecology’. This research area was used as a proxy for the entire field of biology, as it encompasses more than 60 percent of the total scientific production of biology-related research areas, including ‘Plant Sciences’, ‘Zoology’, ‘Oceanography’, ‘Marine and Freshwater Biology’, ‘Evolutionary Biology’, ‘Biodiversity and Conservation’, ‘Entomology’, and ‘Mycology’. The search was finally refined by country (that of the institutional affiliation of any of the co-authors) to obtain the number of publications authored by scientists from each European country. We assigned articles to each country’s record based on the affiliation of authors, taking into account that: (1) scientists may work in a country but not be a national of that country; (2) in publications with multiple authors and institutions, all countries involved were counted, but only once; (3) credit for authorship was assigned “in full” to each country represented rather than using fractional authorship, *e.g.*, in papers with authors from three countries, each country was assigned full credit for the article rather than one-third; and (4) all institutional addresses for an author are included, *e.g.*, an author affiliated with both a French and a Dutch

institution (regardless of the order or the priority) resulted in both France and the Netherlands being “credited”. These criteria, which are consistent with Stocks *et al.* (2008), obviously overestimate the total number of countries represented, but we do not foresee a bias toward any country.

We calculated relative scientific production in tropical biology by dividing overall papers in tropical biology (number of hits for the text string “Tropic*”) by total number of papers in the research area of ‘Environmental Sciences and Ecology’.

Data on total research and development (R&D) professionals in higher education were downloaded from EUROSTAT (http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=rd_p_persocc&lang=en). This included all persons employed directly in R&D, and also those providing direct services such as R&D managers and administrators.

For analyses, we classified European countries by their overseas history in tropical nations. We refer to tropical nations broadly, to include all those nations for which most of their territory (more than 50%) lays within the intertropical band. European countries that were considered to have an overseas history included Belgium, France, Germany, the Netherlands, Portugal, Spain, and the United Kingdom. To be assigned to this category, a country must have had well-established and settled, state-run colonies or protectorates in the tropics (as defined above) of a significant size ($>10^4$ km² at some point in history). Furthermore, at least one of these colonies must have met one of the following criteria: (1) remained a colony for more than 100 yr; (2) remained a colony until the decolonization movement of the 1960s; or (3) retained the colonial language.

After independence, Italy and Denmark were therefore excluded. To test our central hypothesis that European nations with an overseas history contribute more to tropical knowledge, we used a generalized linear model (GLM) where the relative scientific production in the field of tropical biology in each country was fitted as a function of the number of researchers and overseas history (a binary yes/no). An interaction term between number of researchers and overseas history was included in the model. A logit-link function and a binomial error distribution were used. Reduction in deviance by means of chi-squared tests was used as a measure of discrepancy to assess the model’s goodness of fit. All the analyses were conducted with the R software (R Core Team 2017).

RESULTS

In terms of number of scientific papers published in tropical biology between 1975 and 2015, 10,693 papers had at least one (co-) author affiliated to an institution from the United Kingdom, 6934 from France, 6636 from Germany, 3234 from the Netherlands, and 3180 from Spain (Fig. 1A). All other European countries produced less than 3000 scientific papers authored by an individual affiliated with an institution from that country (Fig. 1A), and only 15 countries exceed 500 papers (Table S1).

The ranking in terms of relative scientific production in the field of tropical biology (ratio of tropical biology over total

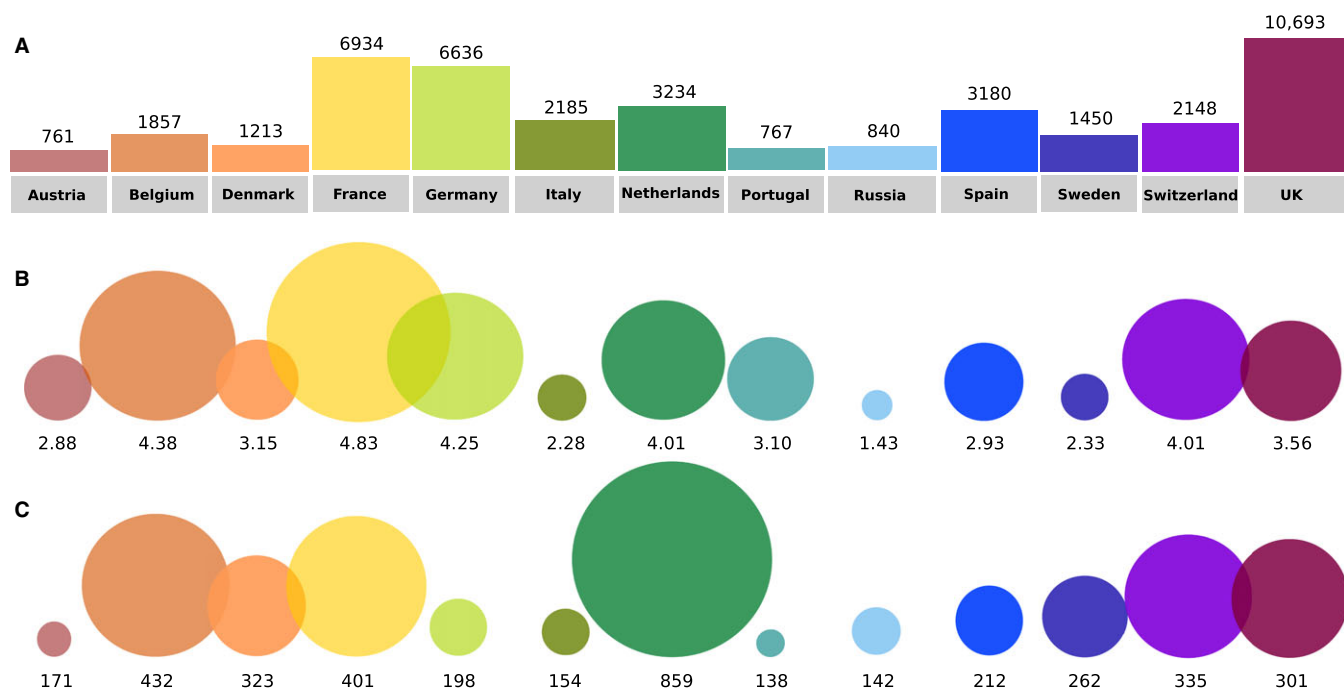


FIGURE 1. Trends in the production of tropical biology literature. Total (a) and relative (b) scientific production of European nations on tropical biology in the area of ‘Environmental Sciences and Ecology’ for the period 1975–2015. The ratio between tropical biological scientific production and number of researchers (no. papers on tropical biology per 10,000 researchers) is also shown (c). Only European countries with the largest overall scientific production (over 700 papers) on tropical biology are shown (see Table S1).

production within the research area of ‘Environmental Sciences and Ecology’) changed slightly, with France at the head of the ranking (4.83%), followed by Belgium (4.38%), Germany (4.25%), Switzerland (4.01%), the Netherlands (4.01%), and the United Kingdom (3.56%) (Fig. 1B). Similarly, when considering number of tropical papers per research effort (number of R&D personnel), the Netherlands (859 papers per 10,000 researchers), Belgium (432), France (402), Switzerland (335), and Denmark (323), occupied the first five positions in the ranking (Fig. 1C, Table S1).

In the GLM, there was a significant effect of overseas history and research capacity on the relative scientific production in tropical ecology (Table 1). According to the model, countries with colonial histories had substantially higher baseline scientific

production than countries without an overseas history. The former colonial countries produced, on average, a larger number of tropical papers relative to their total scientific production in the research area of ‘Environmental Sciences and Ecology’ (Fig. 2). Relative tropical scientific production was also influenced by research capacity (R&D personnel on a log scale), but this depended on overseas history, as indicated by the significant interaction between research capacity and overseas history in the model ($P < 2.2e-16$). For countries without an overseas history, increased research capacity was related to greater relative tropical scientific production, whereas production decreased smoothly with increasing research effort for colonial countries (Fig. 2). Overall, the model explained 56.6 percent of the null deviance (Table 1).

TABLE 1. Factors influencing relative tropical biology literature production. Summary of the generalized linear model testing the effect of (log) number of researchers (log no. researchers) and the existence of historical links with tropical countries (overseas history) on the relative production of tropical biology publications to other literature in ‘Environmental Sciences and Ecology’ for European countries. A logit-link function and a binomial error distribution were used. Reduction in deviance was used as a measure of discrepancy to assess the model’s goodness of fit by means of chi-squared tests.

Terms (added sequentially)	df	Deviance	Exp. Dev.	Resid. df	Resid. Dev.	P
Null				31	6610.7	
Log(no. researchers)	1	1761.0	0.266	30	4849.7	<2.2e-16
Overseas history	1	1836.9	0.278	29	3012.8	<2.2e-16
Log(no. researchers) × Overseas history	1	146.1	0.022	28	2866.7	<2.2e-16

df = Degrees of freedom; Exp. Dev. = Explained deviance; Resid. df. = Residual degrees of freedom; Resid. Dev. = Residual deviance, P = P-value.

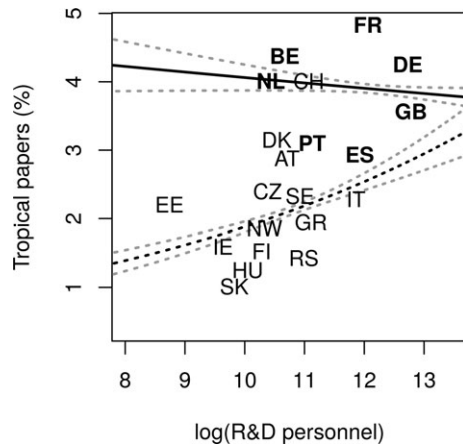


FIGURE 2. Literature production as a function of capacity and overseas history. Modeled observed and predicted (regression lines) values of the relative scientific production (y -axis) in European countries in the field of tropical biology as a function of the number of R&D personnel (x -axis on log scale), and the existence of historical links with tropical countries (dotted line/regular font = no historical link, solid line/bold font = historical link). The 95% confidence interval bands are represented with dotted lines enclosing regression lines. Only those countries with a relative scientific production in tropical biology above one percent are shown: AT = Austria; BE = Belgium; CZ = Czech Republic; DE = Germany; DK = Denmark; EE = Estonia; ES = Spain; FI = Finland; FR = France; GB = Great Britain; GR = Greece; HU = Hungary; IE = Ireland; IT = Italy; NL = Netherlands; NW = Norway; PL = Poland; PT = Portugal; RS = Russia; SK = Slovakia; SE = Sweden; CH = Switzerland.

DISCUSSION

We found that research capacity (R&D personnel on a log scale) had a different effect on relative tropical scientific production depending on overseas history. The positive effect for non-colonial countries may reflect that the larger the research capacity of a country, the more it can diversify its research areas and incorporate disciplines outside a country's primary research priorities (*e.g.*, beyond health, engineering, applied sciences). The slightly negative relationship between research capacity and relative scientific production for colonial countries observed in the model may be caused by countries, such as Belgium or the Netherlands, which have a disproportionately large relative tropical scientific production compared to their small number of R&D personnel. One possible explanation for this pattern is that these countries are small and comparatively low in biodiversity, which may encourage their scientists to seek biological study systems in the tropics. Although smaller countries in Europe are less insular in their research (Ladle *et al.* 2012), there are other plausible explanations for this pattern, including: (1) a legacy of early pioneering researchers and strong tropical research programs (*e.g.*, large natural history museums and herbaria in Belgium and the Netherlands with specimens from early colonial collecting expeditions); (2) a history of training students from tropical countries (Stocks

et al. 2008), who remain affiliated with host institutions and maintain collaborations with European co-authors; and (3) economic investment in national scientific infrastructure for tropical research. For example, the BOLFORS network (Nittler & Nash 1999) promotes the exchange of research and personnel between Bolivia and the Netherlands, increasing the contribution of the Netherlands to tropical biological research overall.

Our results are consistent with the hypothesis that European countries with a history of tropical colonization, exploration, and trade contribute a larger share overall to tropical scientific knowledge and natural history than other European countries. Exceptions to this pattern are instructive of how scientific policy agendas may affect the capacity of countries to conduct biological research in the tropics. For example, some countries without an overseas history such as Switzerland, Denmark, and Austria, have produced relatively large amounts of tropical scientific publications, despite having relatively few language, cultural, or social ties with tropical nations. This may be expected from wealthy but biodiversity-poor countries, and it also emphasizes the importance of policies that actively promote and fund tropical research.

By contrast, countries such as Spain or Portugal, with important colonial histories, do not produce tropical scientific knowledge at the level expected given their cultural, political, and language ties with many tropical countries. Potential explanations for this pattern include: (1) high organismic and ecosystem diversity within these countries (Myers *et al.* 2000) preferentially attracts scientists' attention toward local, rather than distant, systems; and (2) political and scientific agendas of these countries simply do not prioritize research in tropical biology (*e.g.*, MINECO 2013). It is likely that current policies intended to stimulate direct or indirect collaboration with former colonies are not sufficient. However, opportunities do exist for finding flexible sources of support. For example, the European research program ERANET-LAC funds research networks in Latin America (Dangles *et al.* 2016), and can be indirectly used to conduct research in the tropics, even if the program itself is not specifically earmarked for tropical research. Similarly, the US Smithsonian Tropical Research Institute supports the Barro Colorado field station, even though the National Science Foundation does not have a dedicated budget line for research in the tropics.

Our analysis supports the hypothesis that cultural and historic connections facilitate research in the tropics among countries with a colonial past. However, it is important to acknowledge that this relationship is complex, with various socio-economic and cultural factors playing a role, including power relations between formerly colonial 'donor' (Global North) and 'recipient' (Global South) countries, available funding sources for overseas research and, crucially, the presence of field station and experimental research sites. For example, while researchers of all nationalities are drawn to the Brazilian central Amazon, scientists from Portugal and Spain have a distinct advantage in terms of language and cultural familiarity in this region. However, research in this area is dominated by scientists from northern Europe, including the United Kingdom, France, Germany, and the Netherlands. This suggests that the links between researchers

from nations in the Tropics and in the Global North may be weaker for regions that are research hotspots, such as the Amazon (Malhado *et al.* 2014).

WHAT IS IN STORE FOR THE FUTURE?—Despite the universal recognition that most mega-diverse areas occur in the tropics, much of this biodiversity has yet to be formally described and cataloged (Cayuela *et al.* 2009). Tropical biology research should be prioritized in the policy agendas of non-tropical countries of the Global North, as knowledge of tropical systems lags far behind that of less biodiverse temperate regions. In the meantime, tropical biodiversity continues to erode unabated (Wright & Muller-Landau 2006). Because of their cultural, historical, and language ties with many tropical nations, especially in Latin America, European countries such as Spain and Portugal have great opportunity to conduct fruitful biological research in the tropics. Cultural and linguistic ties make the difficult task of field research potentially easier by facilitating discussion (Anderson *et al.* 2015), resolving conflict, and promoting collaboration (Watkins & Donnelly 2005; Stocks *et al.* 2008; Smith *et al.* 2014) among researchers from tropical nations and the Global North. Transcontinental collaborations widen the scope of issues such as biodiversity loss or climate change to a global extent (Dangles *et al.* 2016) and promote economic growth (Stephan 1996).

Finally, the initiative of individual researchers cannot be discounted. Through contributions to biological collections and scientific literature, training students and establishing collaborative research groups, many individual researchers have had a profound influence on the field of tropical biology. Scientific societies, such as the Association for Tropical Biology and Conservation (ATBC) in the United States, or the Society for Tropical Ecology (GTÖ) in Germany, are key to building collaborative engagements and creating a critical mass of researchers that can provide visibility and social awareness for the discipline.

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DATA AVAILABILITY

Data available from the Dryad Repository: <https://doi.org/10.5061/dryad.sj578> (Cayuela *et al.* 2017).

SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article:

TABLE S1. *Summary of literature survey.*

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