

Research Letters

Low contribution of Caribbean-based researchers to academic publications on biodiversity conservation in the insular Caribbean



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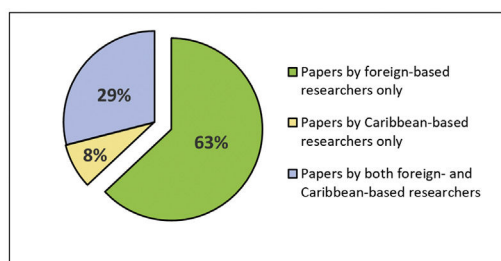
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HIGHLIGHTS

- Review of peer-reviewed literature on biodiversity conservation in insular Caribbean between 2000 and 2015.
- On a per year base, Caribbean-based authors found in 32% of papers, accounted for 22% of lead paper authorships, represented 17% of authors per paper.
- No evidence of improvement in the above metrics over time.
- Marked differences in paper contributions among Caribbean locations, with evidence of low intra-regional collaboration.

GRAPHICAL ABSTRACT



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ABSTRACT

The insular Caribbean is among the most threatened global biodiversity hotspots, warranting urgent and effective action in conservation. However, the capacity of Caribbean-based researchers to address challenges in biodiversity conservation appears limited. To assess the latter, we used the contribution of Caribbean-based authors to the production of peer-reviewed journal papers on biodiversity conservation in the insular Caribbean as a proxy for research capacity. Moreover, because the insular Caribbean is a complex geopolitical system including sovereign states and overseas territories, we examined the contributions of these two groups to the number of papers published. We used the Web of Science Core collection to search for papers by combining the terms “Biodiversity” and/or “Conservation” with either “Carib*” or “Antill*” between 2000 and 2015. This procedure yielded 489 peer-reviewed papers in 145 scientific journals. Over the study period, only 36.6% of all papers included Caribbean-based authors, and Caribbean-based authors accounted for only 17.4% of yearly authorships per paper, with no increases over time. The proportion of papers with only Caribbean-based authors was small (8.0%), although the impact factors of the journals where these papers were published increased over time. Overall, Caribbean-based

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authors from overseas territories produced more papers than those from sovereign states, but this was mainly due to the large contribution of Puerto Rico. Despite facing similar biodiversity challenges, there was little research collaboration between overseas territories and sovereign states. Our results are a call to action to change the status quo in biodiversity research in one of the most biodiversity-rich regions of the world.

Introduction

The insular Caribbean is one of the world's biodiversity hotspots (Hrdina and Romportl, 2017; Myers et al., 2000) and has been a major focus for research in biogeography, evolutionary biology, and conservation biology (Crews and Esposito, 2020; Latta, 2012; Ricklefs and Bermingham, 2008; Sandin et al., 2008; Weaver et al., 2016). Still, there is an urgent need to increase research on Caribbean ecosystems and species. Indeed, several Caribbean-endemic species are vulnerable or threatened with extinction due to habitat loss and fragmentation, climate change, and biological invasions (Bellard et al., 2014; Brooks et al., 2002; Wilson et al., 2011). In addition, new endemic plants (e.g. Macdougall et al., 2018), invertebrates (e.g. Perez-Gelabert, 2020) and vertebrates (e.g. Rodriguez-Silva and Weaver, 2020) are regularly being discovered in the insular Caribbean, while cryptic species may disappear before even being discovered.

Increasing research effort in evolutionary ecology, biogeography, community ecology, population biology, taxonomy, and behavioural ecology will be essential for effective conservation in biodiversity-rich regions (Brito and Oprea, 2009; Buechley et al., 2019; Caro and Berger, 2019; Lucifora et al., 2019). Importantly, to enhance long-term effectiveness and ensure sustainable conservation efforts, it is widely recognized that much of this increase should come as a result of strengthening local research capacity (Biermann, 2001; Campos-Arceiz et al., 2018; Clubbe, 2013; Livingston et al., 2016; Mammides et al., 2016). However, recent analyses indicate that major deficits in local research capacity and productivity still occur in regions corresponding to important hotspots of biodiversity (Livingston et al., 2016; Melles et al., 2019; Tydecks et al., 2018).

The insular Caribbean region consists of a complex geopolitical system of several island groups of overseas territories (OT) falling under the jurisdiction of the larger wealthy developed nations of France, the United Kingdom, the Netherlands and the USA, and 16 sovereign states (SS) falling under the larger umbrella of Small Island Developing States (SIDS). The distinction between SS and OT is important because although both groups face similar local (e.g. habitat loss) and regional (e.g. invasive species) threats to a shared biodiversity and would therefore benefit from a regional collaborative approach, it is reasonable to expect that their OT vs SS status will affect both the quality and quantity of resources that they can allocate to research and development (Gaillard, 2010). In particular, the capacity of SIDS to develop efficient conservation and management policies will depend to a large extent on the scientific knowledge and autonomy of in situ researchers, experts, and managers. Indeed, studies on the vulnerability of SIDS (Commonwealth Secretariat, 1997; Crossley, 2008) have emphasized the strategic importance of human resource development, particularly at the tertiary education and academic research levels, in order to reinforce self-determination while also benefiting from informed international collaboration.

Our main goal here is to provide a quantitative assessment of the contribution of researchers affiliated with Caribbean-based institutions to the production of peer-reviewed papers on biodiversity and conservation in the insular Caribbean over a recent 16-year period (2000–2015). Our specific objectives are: (a) to describe temporal trends in the number of papers and authors per paper with an emphasis on where authors are based (i.e. within or outside the insular Caribbean); (b) to assess changes over time in the

relative contribution of insular Caribbean-based authors to paper authorship using different metrics; (c) to investigate the relationship between the journal impact factor of the published papers and where authors are based (e.g. foreign- vs Caribbean-based); (d) to assess the relative contribution of authors from OT and SS to the production of papers; and (e) describe the geographic configuration of collaborations among Caribbean-based authors.

Methods

The Clarivate Analytics Web of Science Core collection was searched on June 16, 2016 for papers using either one of the two keywords “Biodiversity” and “Conservation” along with either “Carib*” or “Antill*” in the “All fields” search option, for the 2000–2015 time period. The four combinations yielded 528 papers, out of which 30 were subsequently removed from the data set as their content was not relevant to biodiversity or conservation in the insular Caribbean. Nine papers were also removed as these were conference proceedings that were not peer-reviewed. The 489 remaining papers were distributed among 145 scientific journals (see Supplementary material).

All the papers were individually examined to extract the year of publication, the impact factor (Journal Citation Reports 2015), the number of authors, the country of affiliation of all authors, and the position of each author within the authorship list (first author, last author or other position). An author with an official affiliation in the insular Caribbean, whether a sovereign state (SS) or an overseas territory (OT), was considered a Caribbean-based author. However, in some of the analyses, we distinguished between authors from SS and OT. Note that our focus in this study was on Caribbean-based authors, thus Caribbean-born authors based abroad were not considered as ‘Caribbean-based’ in these analyses, while foreign-born authors living and working in the Caribbean were.

We used generalized linear models (GLM) (Zuur et al., 2007) to describe temporal trends in selected metrics and investigate the potential role of several factors. To assess the temporal trend of the total number of papers and number of authors per paper, while accounting for overdispersion, we used a quasi-Poisson generalized linear model (GLM) with the total number of papers or number of authors per paper in a year as the response variables and year as predictor. We also assessed whether trends in the total number of papers differed among three categories of authorship papers: papers with only authors based outside the insular Caribbean (foreign-based), papers with collaborations between authors based in the insular Caribbean and those based outside the region (Caribbean- and foreign-based), and papers with only insular Caribbean-based authors (Caribbean-based). The latter analysis involved using a quasi-Poisson GLM with the total number of papers in a year as a response variable and year, authorship category and their interaction as predictors.

Moreover, we used a quasi-binomial GLM to assess whether the proportion of Caribbean-based authors per paper had changed over time and whether it depended on the number of authors in a paper. The latter implied using the proportion of Caribbean-based authors in the authorship list of a given paper as response variable and the corresponding year and number of authors in the paper (and their interaction) as predictors. We also used a binomial GLM to test for the effect of time and number of authors on the proportion of papers that included Caribbean-based authors as well as on the proportion

of papers that were led by Caribbean-based authors. This implied using the presence/absence of Caribbean-based authors in a paper as a binary response variable and year and number of authors (and their interaction) as predictors. A paper led by a Caribbean-based author was defined as any paper in which the first or last author was Caribbean-based. Moreover, focusing only on the subset of papers that did include Caribbean-based authors, we used a binomial GLM to test for the effect of time and number of authors on the proportion of these papers that were also led by Caribbean-based authors.

We also assessed temporal trends in the impact factor of the journal of publication of the papers for each of the three aforementioned authorship categories and assessed the relationship between the number of authors and impact factor. Here we used a Gaussian GLM with the paper's corresponding (log-transformed) impact factor as response variable and year (as a numerical variable), number of authors, and authorship type (categorical variable) as predictors in a three-way interaction. One of the 489 papers did not yet have an impact factor assigned to the journal of publication in 2015, so it was removed from this specific analysis.

Furthermore, focusing only on papers including Caribbean-based authors, we assessed whether temporal trends in total number of papers differed among three different categories of papers: papers with authors based only in OT (*OT only*), papers with authors based in both SS and OT (*SS & OT*), and papers with authors based only in SS (*SS only*). This analysis involved using a Gaussian GLM with the (square root-transformed) number of papers in a year as response variable and year, author location (and their interaction) as predictors. This model was preferred over a quasi-Poisson GLM because it provided an adequate fit to the data as evidenced by residual plots, but had greater statistical power.

In all cases, full models were simplified by removing non-significant terms ($p > 0.05$) (when present) based on analyses of deviance using either Chi-square tests (binomial GLM) or F-ratio tests (quasi-Poisson, quasi-binomial and Gaussian GLM) (Zuur et al., 2007). Where relevant, data and corresponding fits of the final models (along with 95% confidence bands) are shown graphically. A summary table with the model parameter estimates is also provided. Generalized model fitting was conducted with the “stats” package in R version 4.0.1 (R Core Team, 2019). Graphic representation of data and model fits was conducted using the “ggplot2” (Wickham, 2016), “interaction” (Long, 2019) and “jtool” (Long, 2020) packages. We used a significance level of 0.05 for all statistical tests. Adequate model fit was assessed by examination of residual plots.

Finally, to describe research collaborations among Caribbean locations (whether SS or OT) over the 16-year study period, we first built a connectivity matrix based on the numbers of collaborative papers between pairs of locations (see Supplementary Material) and then used the “igraph” (Csardi and Nepusz, 2006) package to plot the matrix as a network.

Results

Journal overview

Of the 145 scientific journals with the 489 papers related to biodiversity conservation in the insular Caribbean for the period 2000–2015, eleven jointly accounted for 40% of all published papers. These were PLOS One (40 papers), Molecular Ecology (20), Molecular Phylogenetics and Evolution (20), Biological Conservation (18), Caribbean Journal of Science (18), Coral Reefs (18), Marine Ecology Progress Series (18), Conservation Biology (13), Revista de Biología Tropical (13), Conservation Genetics (9) and Zootaxa (9).

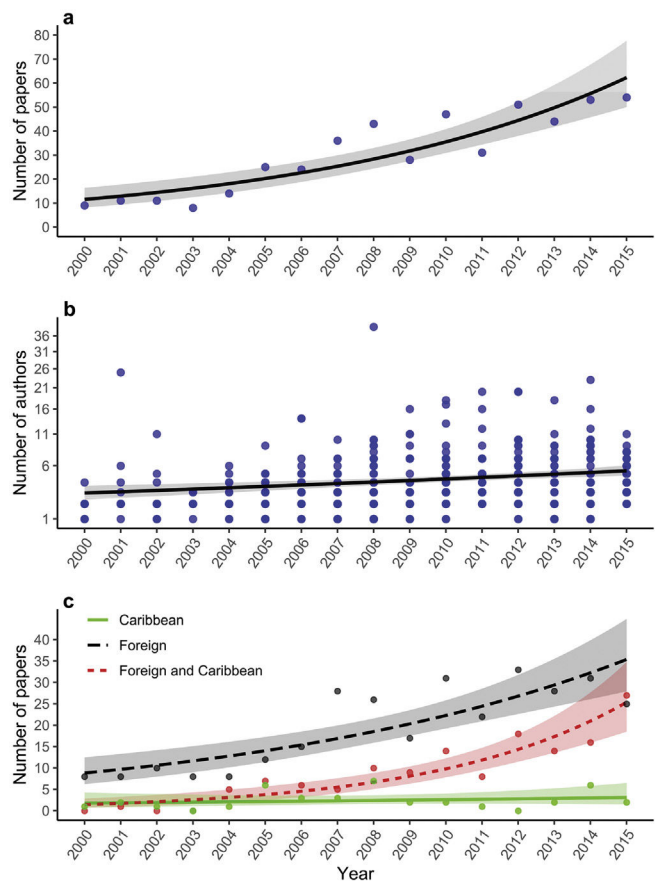


Fig. 1. Temporal trends (period 2000 to 2015) in peer-reviewed papers on biodiversity conservation in the insular Caribbean shown as (a) total number of papers (all authorship categories combined), (b) number of authors per paper, and (c) number of papers as a function of authorship category. Generalized linear model (quasi-Poisson) fits of the number of papers or authors as a function of year are shown as lines (along with corresponding 95% confidence bands).

Number of papers published: Overall findings and temporal trends

Overall, papers with only foreign-based authors accounted for 63.4% of the total number of papers, followed by papers with both Caribbean-based and foreign-based authors with 28.6%. Papers with only Caribbean-based authors accounted for 8.0% of the total number of papers. The total number of papers increased over time, going from 9 papers observed in 2000 to 54 in 2015 (Fig. 1a; Model A in Tables 1 and 2). There was also a significant increase in the number of authors per paper over the same period (from 1.7 authors per paper in 2000 to 4.4 in 2016; Fig. 1b; Model B in Tables 1 and 2).

Temporal trends in the number of papers differed significantly among authorship categories, as evidenced by a statistically significant interaction between year and authorship category (Model C in Tables 1 and 2). Papers by Caribbean-based authors did not increase significantly over time (Fig. 1c; Model C in Table 2). In contrast, papers by foreign-based authors and by both Caribbean- and foreign-based authors did increase over time (Fig. 1c), although only the latter category showed a rate of increase that was significantly larger than that of the Caribbean-based authors (Model C in Table 2).

The proportion of Caribbean-based authors per paper remained low over the entire 16-year period, with an overall average of 17.4% of all authors per paper per year ($\pm 8.0\%$ standard deviation, $n = 16$) (Fig. 2a). The odds of having a Caribbean-based author in a paper did not change significantly over time, but decreased significantly

Table 1

Description of nine full generalized linear models (GLM) (from A to I) and corresponding analysis of deviance outputs. The full models were subsequently reduced by removing non-significant ($p > 0.05$) terms. Bold font indicates terms finally retained for each reduced model. The parameter estimates (and associated standard errors) of the reduced models are provided in Table 2. Df: degrees of freedom; Dev: deviance; Resid Df.: Residual degrees of freedom; F: test statistic for the quasi-Poisson, quasi-binomial and Gaussian models (a Chi-square test was used for the binomial models).

Model	Model description	Model terms (added sequentially)	Df	Dev	Resid. Df	Resid. Dev.	F	P-value
A	Quasi-Poisson GLM (log link) with total number of papers as a function of year.	Null			15	149.8		
		Year	1	121.5	14	28.3	58.9	<0.0001
B	Quasi-Poisson GLM (log link) with number of authors in a paper as a function of year.	Null			488	1113.9		
		Year	1	52.3	487	1061.5	16.6	<0.0001
C	Quasi-Poisson GLM (log link) with number of papers in a year as a function of year, authorship category and their interaction. Authorship categories are in the following order: Caribbean-based, foreign-based, and both foreign- & Caribbean-based.	Null			47	458.1		
		Year	1	121.5	46	336.5	75.2	<0.0001
		Authorship	2	244.4	44	92.1	75.6	<0.0001
		Year : Authorship	2	20.0	42	72.2	6.2	0.0044
D	Quasi-binomial GLM (logit link) with proportion of Caribbean-based authors in a paper as a function of total number of authors, year and their interaction.	Null			488	1137.6		
		Number of authors	1	13.5	487	1124.1	6.0	0.0148
		Year	1	0.0	486	1124.1	0.0	0.9484
E	Binomial GLM (logit link) with presence/absence of Caribbean-based authors in a paper as a function of total number of authors, year and their interaction.	Number of authors : Year	1	3.8	485	1120.3	1.7	0.1956
		Null			488	642.4		
		Number of authors	1	33.3	487	609.0	–	<0.0001
F	Binomial GLM (logit link) with presence/absence of lead Caribbean-based authors in a paper as a function of total number of authors, year and their interaction.	Year	1	2.8	486	606.3	–	0.0953
		Number of authors : Year	1	1.2	485	605.1	–	0.2787
		Null			488	538.1		
G	As in (F), but with only data for papers including Caribbean-based authors.	Number of authors	1	1.0	487	537.1	–	0.3212
		Year	1	0.4	486	536.8	–	0.5417
		Number of authors : Year	1	1.1	485	535.7	–	0.3028
J	Linear Gaussian GLM (identity link) with log-transformed impact factor of a paper as a function of number of authors, year, authorship category and their interactions. Authorship categories are in the following order: Caribbean-based, foreign-based, and both foreign- & Caribbean-based.	Null			487	446.9		
		Number of authors	1	13.4	486	433.4	16.4	<0.0001
		Year	1	0.6	485	432.8	0.7	0.3928
I	Linear Gaussian GLM (identity link) with square root-transformed number of papers including Caribbean-based authors in a year as a function of year, author location and their interaction. Author locations are in the following order: both Sovereign States & Overseas territories (SS & OT), SS only, and OT only.	Authorship	2	28.4	483	404.5	17.3	<0.0001
		Number of authors : Year	1	0.0	482	404.4	0.0	0.9192
		Number of authors : Authorship	2	1.3	480	403.2	0.8	0.4570
I	Linear Gaussian GLM (identity link) with square root-transformed number of papers including Caribbean-based authors in a year as a function of year, author location and their interaction. Author locations are in the following order: both Sovereign States & Overseas territories (SS & OT), SS only, and OT only.	Year : Authorship	2	12.1	478	391.1	7.4	0.0007
		Number of authors : Year : Authorship	2	1.6	476	389.5	1.0	0.3829
		Null			47	75.6		
I	Linear Gaussian GLM (identity link) with square root-transformed number of papers including Caribbean-based authors in a year as a function of year, author location and their interaction. Author locations are in the following order: both Sovereign States & Overseas territories (SS & OT), SS only, and OT only.	Year	1	20.2	46	55.3	52.1	<0.0001
		Location	2	29.4	44	25.9	37.9	<0.0001
		Year : Location	2	9.6	42	16.3	12.3	<0.0001

as the number of authors per paper increased (Fig. 3a; Model D in Tables 1 and 2).

The proportions of papers including Caribbean-based authors and those led by Caribbean-based authors also remained low throughout the entire 16-year period (Fig. 2b and c), with an observed average of 31.9% of papers per year ($\pm 15.0\%$ SD) and 22.0% of papers per year ($\pm 11.6\%$), respectively. The odds of having papers of either type did not significantly change over time (Models E and F in Table 1). In contrast, there was a significant and positive effect of the number of authors on the odds of having a paper including Caribbean-based authors (Fig. 3b; Model E in Tables 1 and 2), but not on the odds of having a paper led by Caribbean-based authors (Model F in Table 1).

Finally, when only papers including Caribbean-based authors were considered, the proportion of these papers that were also led by Caribbean-based authors decreased over time, going from 100% in 2000 to 62.1% in 2015 (Fig. 2d). The odds of having such a paper led by Caribbean-based authors significantly decreased over time, after accounting for the effect of number of authors (Fig. 4a; Model G in Tables 1 and 2). Moreover, these odds were also significantly

and negatively related with the number of authors, after accounting for the effect of time (Fig. 4b; Model G in Tables 1 and 2).

Paper impact factor: Overall findings and temporal trends

The median impact factor of papers with only foreign-based authors and of papers with both Caribbean- and foreign-based authors over the entire 16-year period was relatively similar at 2.275 (1st and 3rd quartiles: 1.589 and 3.916) and 2.844 (1st and 3rd quartiles: 0.245 and 3.299), respectively. In contrast, the median impact factor of papers with only Caribbean-based authors over the same period was considerably lower at 1.065 (1st and 3rd quartiles: 0.4385 and 3.279). However, the impact factor of Caribbean-based papers steadily increased over time and reached values similar to those of the other two categories by the end of the study (Fig. 5a). This difference in trends in impact factor between authorship categories was confirmed by the model selection, which retained an interaction term between year and authorship category in addition to the number of authors as predictors (Model J in Tables 1 and 2). It also indicated that the log (impact factor) sig-

Table 2

Parameter estimates and associated statistics of eight reduced generalized linear models (GLM) (from A to I; model descriptions are given in Table 1). Std. Error: standard error; statistic value: *t* test statistic except for E and G (Z statistic).

Model	Parameter	Estimate	Std. Error	Statistic value	p-value
A	Intercept	-222.40	30.60	-7.27	<0.001
	Year	0.11	0.02	7.38	<0.001
B	Intercept	-79.92	20.34	-3.93	<0.001
	Year	0.04	0.01	4.00	<0.001
C	Intercept	-70.97	89.41	-0.79	0.432
	Year	0.04	0.04	0.80	0.426
	Authorship (Foreign)	-111.47	95.37	-1.17	0.249
	Authorship (Foreign and Caribbean)	-308.16	106.29	-2.90	0.006
	Year : Authorship (Foreign)	0.06	0.05	1.19	0.241
	Year : Authorship (Foreign and Caribbean)	0.15	0.05	2.91	0.006
D	Intercept	-1.23	0.13	-9.31	<0.001
	Number of authors	-0.04	0.02	-2.28	0.023
E	Intercept	-1.29	0.17	-7.48	<0.001
	Number of authors	0.17	0.03	5.10	<0.001
G	Intercept	240.8	114.0	2.1	0.035
	Number of authors	-0.38	0.07	-5.28	<0.001
	Year	-0.12	0.06	-2.09	0.037
J	Intercept	-235.31	70.47	-3.34	<0.001
	Number of authors	0.05	0.01	4.51	<0.001
	Year	0.12	0.04	3.34	<0.001
	Authorship (Foreign)	271.49	74.97	3.62	<0.001
	Authorship (Foreign and Caribbean)	297.17	83.92	3.54	<0.001
	Year : Authorship (Foreign)	-0.13	0.04	-3.61	<0.001
I	Year : Authorship (Foreign and Caribbean)	-0.15	0.04	-3.54	<0.001
	Intercept	-7.32	67.88	-0.11	0.915
	Year	0.00	0.03	0.11	0.910
	Location (SS only)	-409.30	95.99	-4.26	<0.001
	Location (OT only)	-412.80	95.99	-4.30	<0.001
	Year : Location (SS only)	0.20	0.05	4.28	<0.001
Year : Location (OT only)	0.21	0.05	4.32	<0.001	

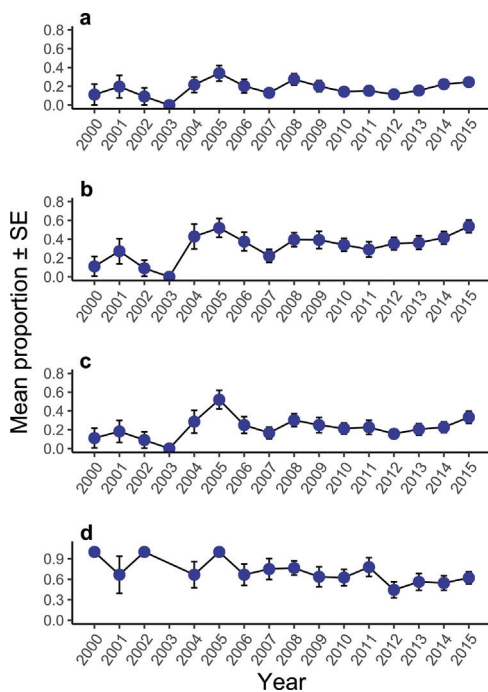


Fig. 2. Temporal trends (period 2000 to 2015) in the contribution of insular Caribbean-based authors to the production of peer-reviewed papers on biodiversity conservation in the insular Caribbean shown as (a) average proportion of Caribbean-based authors per paper, (b) average proportion of papers including at least one Caribbean-based author, (c) average proportion of papers led by a Caribbean-based author, and (d) average proportion of papers with Caribbean-based authors also led by a Caribbean-based author.

nificantly increased with the number of authors, after accounting for the interactive effect of authorship category and year (Fig. 5b; Model J in Table 2).

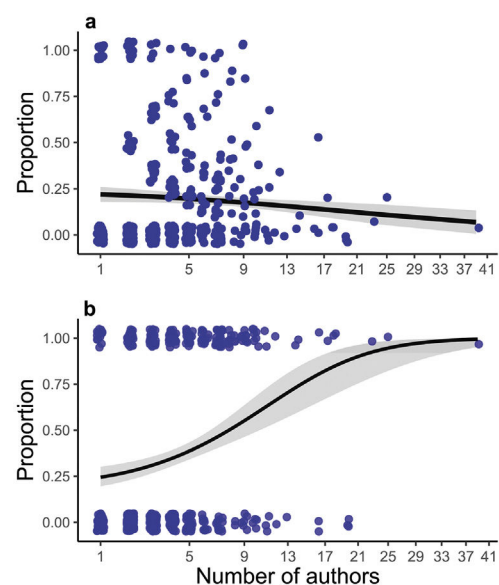


Fig. 3. Modelled effects of the number of authors on (a) the proportion of Caribbean-based authors per paper, and (b) the proportion of papers including at least one Caribbean-based authors between 2000 and 2015, using a quasi-binomial and a binomial GLM, respectively. Solid black lines and grey enveloping bands show model fits and corresponding 95% confidence intervals. Blue circles are the 489 papers (some jitter was added to their position to help visualization).

Role of sovereign states (SS) versus overseas territories (OT) in the number of papers published

Focusing only on the papers that included Caribbean-based authors, but distinguishing among papers with authors based in SS versus those based in OT revealed marked differences in their respective contributions to the total number of papers published.

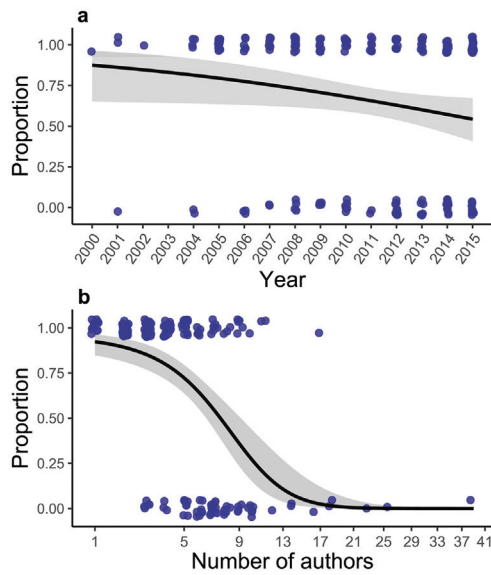


Fig. 4. Modelled effects of (a) year and (b) number of authors on the proportion of papers including Caribbean-based authors that were also led by Caribbean-based authors between 2000 and 2015 using a binomial GLM. Solid black lines and grey enveloping bands show model fits and corresponding 95% confidence intervals. Blue circles are the 489 papers (some jitter was added to their position to help visualization).

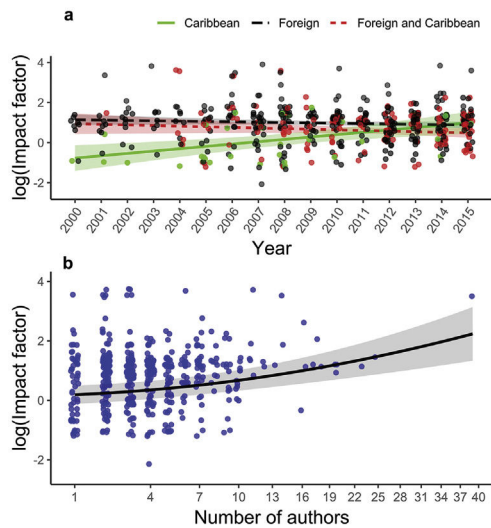


Fig. 5. Modelled effects of (a) year and authorship category and (b) number of authors in a paper on the (log-transformed) impact factor of 488 papers (circles) between 2000 and 2015 using a Gaussian GLM. The various lines and enveloping bands show model fits and corresponding 95% confidence intervals. Some jitter was added to the position of the papers (circles) to help visualization.

Indeed, over the entire 16-year period the majority of the papers (58.1%) came exclusively from OT (*OT only*), followed by papers from SS (*SS only*; 38.0%), with a negligible contribution of papers from collaborations between authors based on both OT and SS (*SS & OT*; 3.9%). There were also marked differences in observed trends among these categories. *SS only* and *OT only* papers increased similarly overtime whereas *SS & OT* papers did not increase (Fig. 6). The difference in temporal trend between *SS & OT* papers and the other two categories was confirmed statistically by a significant interaction between year and author location (Model I in Table 1), with *SS only* and *OT only* papers exhibiting nearly identical slope estimates (Model I in Table 2). In fact, re-running the analysis after excluding *SS & OT* papers confirmed that rates of increase did not differ

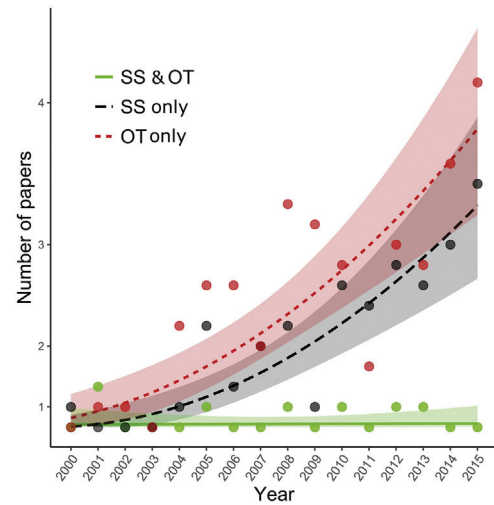


Fig. 6. Modelled effects of year and Caribbean-based author location on the (square root transformed) number of papers (circles) that included at least one Caribbean-based author between 2000 and 2015 using a Gaussian GLM. The various lines and enveloping bands show model fits and corresponding 95% confidence intervals. Location is determined by whether authors in a paper were based on overseas territories (*OT only*), sovereign states (*SS only*), or a combination of both (*SS & OT*). Note that the response variable was back transformed for plotting.

significantly between *SS only* and *OT only* (location × year interaction: $p = 0.968$), whereas there was a significant effect of both year ($p < 0.001$) and location ($p = 0.0312$) in the simplified model, with *OT only* consistently producing more papers than *SS only* at any given time (Fig. 6).

Further comparing *SS only* and *OT only* papers (which jointly accounted for 96.1% of papers with Caribbean-based authors) indicated that both categories were largely dominated by papers involving collaborations with foreign-based authors (76.0% of papers for *SS only* and 82.4% for *OT only*). These proportions did not differ significantly between both categories over the study period (chi-square test: $X^2 = 0.652$, d.f. = 1, $p = 0.419$). Moreover, there were no significant differences between both categories in log (impact factor) (Gaussian GLM: $F = 2.02$, d.f. = 1, 169, $p = 0.1569$) nor in the number of authors per paper (quasi-Poisson model: $F = 0.36$, d.f. = 1, 170, $p = 0.5475$) over the study period.

The USA overseas territory of Puerto Rico accounted alone for nearly 23.7% of all paper authorships (Fig. 7; Fig. S1 in Supplementary material). This was followed by the sovereign state of Cuba, accounting for nearly 12.8% of all paper authorships (Fig. 7; Fig. S1). Other important OT contributors were the USA Virgin Islands and Curacao (Netherlands OT) with 9.5% and 8.5% of all paper authorships, respectively (Fig. 7; Fig. S1). Other important sovereign state contributors were Jamaica (5.7%) and the Dominican Republic (5.2%; Fig. 7; Fig. S1). Comparatively, on the lower end, two SS (Haiti and Antigua & Barbuda) and one British OT (Anguilla) each accounted for only 0.6% of all paper authorships (Fig. 7; Fig. S1).

Caribbean-based collaborations

A closer look into the level of collaboration among Caribbean-based authors from different insular Caribbean locations (whether SS or OT) showed that, overall, 58.3% of all paper authorships involved collaborations with foreign-based authors, but not with Caribbean-based authors from other locations. This was followed by 19.9% of paper authorships that included both foreign-based as well as Caribbean-based authors from other locations, and by 15.6% of paper authorships that did not involve collaborations with any authors from other locations (whether foreign- or

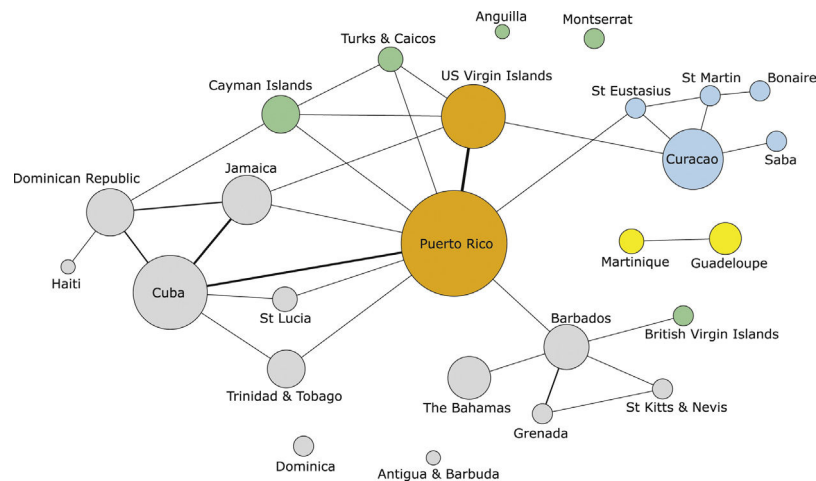


Fig. 7. Connectivity network showing paper collaborations between 2000 and 2015 among locations (circles) that were Sovereign States (grey fill) and Overseas Territories (British: green fill; French: yellow; USA: orange; Netherlands: light blue) as well as the relative contribution of each location to total number of papers published (which is proportional to circle diameter). The width of the line connecting pairs of locations is proportional to the number of paper collaborations between locations.

Caribbean-based). Finally, only 6.2% of paper authorships involved collaborations with Caribbean-based authors from other locations, but not with foreign-based authors.

The connectivity network showing paper collaborations among Caribbean locations (whether SS or OT) revealed a few small collaboration networks over the entire 16-year period (Fig. 7). The French OT (Guadeloupe and Martinique) had collaborated between themselves, but not with other locations in the region (Fig. 7). Most of collaborations of the Netherlands OT (Saba, Curacao, St Eustasius, St Martin and Bonaire) had taken place among themselves (Fig. 7). The OT of the USA (Puerto Rico and US Virgin Islands) shared a relatively large number of intra-collaborations (Fig. 7). Another small network of collaborations involved Barbados, St Kitts and Nevis, Grenada, the Bahamas, and the British Virgin Islands (Fig. 7). The last conspicuous network involved the Greater Antilles (Cuba, the Dominican Republic, Puerto Rico, Jamaica and, to a lesser extent, Haiti) (Fig. 7). In contrast, a couple of SS (Dominica and Antigua & Barbuda) and British OT (Montserrat and Anguilla) lacked collaborations with other locations during the study period (Fig. 7). Finally, Puerto Rico, in addition to being the major contributor to the total number of papers published, was the location most likely to be involved in collaborations with other locations across the region, whether SS or OT, thus helping connect most research networks (Fig. 7).

Discussion

Contribution of Caribbean-based authors to the literature

Our survey of the peer-reviewed literature on biodiversity conservation in the insular Caribbean region between 2000 and 2015 has revealed a low contribution of Caribbean-based authors as measured by a variety of metrics. We found that both the total number of papers published and number of authors per paper increased over time and this translated into multi-author papers with at least one Caribbean-based author being the most rapidly growing contribution to the literature. However, the latter came with no concomitant increases over time in the relative contribution of Caribbean-based authors to paper authorship, whether measured as the proportion of authors that were Caribbean-based or the proportion of papers that included at least one Caribbean-based author or which were led by a Caribbean-based author. In fact, when we focused only on papers that included at least one Caribbean-based

author, we found that the proportion of such papers that were also led by a Caribbean-based author decreased over time.

Independently of time, we found contrasting effects of the number of authors in a paper on the contribution of Caribbean-based authors to paper authorship. Whereas increases in the number of authors led to higher odds of having at least one Caribbean-based author in a paper, it also led to lower odds of having additional Caribbean-based authors in the authorship, and had no effect on the odds of having a paper led by Caribbean-based authors. Our results are thus in line with a global pattern of increased inclusion of authors from the Global South via multi-author collaborations, but without necessarily reflecting any improvement in the relative contribution of such authors to lead (and/or corresponding) paper authorships (Gonzalez-Alcaide et al., 2017; Malhado et al., 2014; Mammides et al., 2016). This is in line with recent studies showing a persistent under-representation of the Global South in biodiversity conservation science (Campos-Arceiz et al., 2018; Espin et al., 2017; Gaillard, 2010; Livingston et al., 2016; Melles et al., 2019; Stocks et al., 2008; Tydecks et al., 2018).

A decrease in the contribution of Caribbean-based authors to both paper authorship and lead authorship as the number of authors increases might simply faithfully reflect the respective contributions of all authors, since foreign-based authors will often have greater access to the funding and cutting-edge technology (and associated know-how) (Dangles et al., 2016; Habel et al., 2016; Malhado et al., 2014); this would facilitate foreign-based authors leading the research effort. However, in other instances, this might result from questionable practices. For example, it might reflect an obligation of foreign-based authors to associate local Caribbean-based authors to their projects to either be eligible for cooperation programs with the Global South or to obtain relevant permits from local authorities (Barber et al., 2014; Habel et al., 2016), even though the Caribbean-based authors made negligible contributions. Independently of the reasons for this underrepresentation, persistent non-lead authorships could ultimately be detrimental to the careers and international recognition of Caribbean-based authors. This might also stall the much-needed increase in the representation of biodiversity-rich regions among editors and reviewers of conservation journals (Espin et al., 2017; Primack et al., 2017).

We found that the impact factor of a paper increased with the number of authors per paper, and this was the case irrespective of authorship origin, which is qualitatively consistent with the observation that collaborations tend to yield papers of higher

global significance in the natural and social sciences (Larivière et al., 2015). More interestingly, we found that, over the entire study period, papers by only Caribbean-based authors were associated with a lower impact factor than those that included foreign-based authors. However, our findings also indicated that the impact factor of papers published by only Caribbean-based authors increased steadily over the 16-year period, reaching levels similar to those of the two other authorship categories. Although this may indicate an improvement in the global significance of local research capacity, such improvement was not matched by a concomitant increase over time in the total number of papers produced solely by Caribbean-based authors. Thus, without collaboration with foreign-based authors, important limitations to the production of papers in journals with high impact factor persist within the region.

Different non-mutually exclusive factors can help explain the lower number of papers published by Caribbean-based authors, particularly in journals with high impact factor. These factors include among others: research mainly focused on addressing locally relevant problems; a pervasive lack of access to research funding and cutting-edge research technology; an insufficient number of well-equipped biological stations across the region; high teaching loads for academic staff; limited opportunities for training and conference attendance; low access to international journals; language barriers; low incentives for peer-reviewed publications by post-graduate students; and low interest in pursuing careers in conservation (see Table S1 in Supplementary material for further details). Many of these factors apply to other biodiversity-rich regions of the Global South (e.g. Barber et al., 2014) and operate under a persistent background of “brain drain” emigration (Gaillard, 2010; Mishra, 2006). We do, however, acknowledge that the relative importance of these diverse factors is likely to vary considerably within the insular Caribbean region due to differences in historical context (see below).

An intra-regional perspective

Caribbean-based authors in OT consistently produced more papers than those from SS, even though both groups were equally likely to engage in collaborations with foreign-based authors. However, there is a high variability in the number of papers within both OT and SS. Indeed, the USA OT of Puerto Rico singlehandedly accounted for about ¼ of all Caribbean-based publications, in spite of its population size being only about 1/3 of that of larger locations such as Cuba, the Dominican Republic and Haiti (UN, 2019), making this OT by far the major Caribbean-based contributor to the number of papers published.

The disproportionate overall contribution of Puerto-Rico to the number of papers published in the region has been corroborated independently and goes beyond the life sciences (Ortiz-Rivera et al., 2000). This likely partly reflects the fact that Puerto Rico has one of the best records globally in education development over the past 50 years, leading to a relatively high proportion of college-educated adults (Ladd and Rivera-Batiz, 2006) and to a large base of adequately-trained human resource capacity. As such, the important relative contribution of Cuba for the sovereign states might better reflect the fact that Cuba not only has the largest human population of the insular Caribbean, but that it also has one of the highest proportions of university-educated adults in the region (Roser and Ortiz-Ospina, 2013). Given the contrasting historical, socio-economic and political contexts of Puerto Rico and Cuba, with the latter suffering from the embargo imposed by the USA, our findings suggest that, despite the cultural, linguistic and socio-economic heterogeneity that exists within the insular Caribbean, investment in tertiary-level or higher education remains one necessary condition to increase local research capacity in biodiversity conservation. In that regard, and despite a significant development

of the insular Caribbean university system over the last 50 years (Cobley, 2000), several SS still rely on a few small universities with limited funding (Obino et al., 2017) and interdisciplinary research capacity (CDKN, 2012). In any case, there is great need for a more historically-informed understanding of how local institutions (universities, research stations, government agencies, NGOs) across the region have embraced (or not) research in disciplines related to biodiversity conservation to help guide the way forward; gaining such understanding will likely require directed surveys (Gaillard, 2010), more interdisciplinary communication, and input from historians of science in the region.

Our results provide insights into intra-regional cooperation in research on biodiversity in the insular Caribbean. Only about one quarter of all paper authorships involved collaborations among Caribbean-based authors from other locations within the insular Caribbean region (whether SS or OT). In fact, when authors from outside the Caribbean (foreign-based) were not involved, Caribbean-based authors were more likely to publish on their own (or with authors from the same Caribbean location) than via collaborations with authors from other Caribbean locations (whether SS or OT). Our analysis also revealed a fragmented landscape with just a few small research networks, most of which appeared to reflect geopolitical legacies (notably the OT clusters of France, the Netherlands and the USA), supporting a particularly important role of cultural and historical post-colonial connections among locations in scientific production (Cayuela et al., 2018). In contrast, only one network, that of the Greater Antilles, seemed to capture high strategic importance in biodiversity conservation. Thus, despite sharing a large fraction of biodiversity and a number of threats to such biodiversity, such as biological invasions (e.g. Betancur-R et al., 2011), we found little evidence of strong collaboration. Some of the factors that likely hinder such collaborations include the relatively high cost of travelling between locations within the region and language barriers. In relation to the latter, the official bilingual status of Puerto Rico (English and Spanish) might help explain why it was also the most inter-connected location.

Where do we go from here?

The insular Caribbean is one of the most rewarding areas for research on biodiversity and evolution in the world and is also one of the most threatened (Brooks et al., 2002; Myers et al., 2000). We also agree with the contention that tackling global environmental problems will require the rapid development of ecology science in the Global South (Livingston et al., 2016). As such, one would expect the numerous research programs implemented there by foreign-based research teams to contribute to increasing the productivity of Caribbean-based researchers through direct cooperation, training and capacity building. Indeed, global increases in scientific cooperation between countries of the Global South and the Global North in tropical ecology and conservation in recent years have been reported (Dangles et al., 2016; Malhado et al., 2014; Perez and Hogan, 2018). However, these same reports also acknowledge that more needs to be done to integrate underrepresented countries of the Global South. Our results for the insular Caribbean are qualitatively consistent with this assertion.

We recognize that the present study is based on a conservative sampling of the peer-reviewed journal literature pertaining to biodiversity conservation research. By definition, it necessarily ignores the production of unpublished academic research (e.g. graduate and undergraduate theses) and grey literature (e.g. technical reports) by Caribbean-based researchers, because these publications are difficult to rigorously quantify and will have a limited reach at the global level. It also excludes peer-reviewed journals not listed in the Web of Science Core collection, which might introduce a bias against regional and/or non-English journals of the

Global South (Alonso and Fernández-Juricic, 2002; Holmgren and Schnitzer, 2004; Nuñez and Amano, 2021). This diversity of scientific contributions certainly deserves to be examined in future studies to provide a more complete picture. Still, in the context of global visibility and relevance, we believe that insights from this preliminary assessment provide a valuable starting point for taking positive action.

We believe that the complexity of socio-political systems in the insular Caribbean, their colonial histories, and consequent combination of SS and OT, may call for a reconsideration of some of the solutions that have been advocated so far to increase the representation of the Global South in biodiversity conservation science. Adding Caribbean-based editors to the editorial boards of ecology and conservation journals and/or waiving publication costs for authors from the Global South (Campos-Arceiz et al., 2018; Livingston et al., 2016; Mammides et al., 2016; Nuñez et al., 2019) is important and may help increase the relative contribution of Caribbean-based authors, but only to a point. Indeed, like elsewhere, the ability of the Caribbean-based scientific community to produce data of sufficient quality to match the standards of international journals critically depends upon the availability of local qualified scientists. Our data showing an increase in impact factor over the 16-year period for papers involving only Caribbean-based authors support that highly qualified Caribbean-based researchers already exist within the region. However, the lack of an increase in the number of papers published over time in the absence of foreign-based authors, coupled with the marked differences among locations in paper production, supports that more are needed.

Therefore, we suggest that the first priority should be building research capacity in conservation science in the insular Caribbean. In that respect, although we do not question an important role for short-term internships in helping increase interest and in providing some training in technical skills in biodiversity research (e.g. Latta and Faaborg, 2009), we argue that this alone is not enough. Short term internships come with the risk of maintaining young Caribbean-based naturalists in a subordinate role, relegating them to a technical task force supporting research and monitoring programs designed and led by foreign-based researchers.

We propose that the ultimate goal of capacity building in the region should be the development of a collective scientific expertise, i.e. the constitution of a culturally-diverse network of multilingual Caribbean-based scientists with diverse and complementary skills, sharing a common and strong theoretical background in ecology, evolution and conservation biology, and forming a cohesive academic force capable of orienting conservation strategies and informing policies. Ideally, such a network would help improve the current poor record of intra-regional collaborations and re-configure the current map of collaboration networks, aligning it with research priorities shared within the region, improving the understanding of impacts, and enhancing the sharing of information and facilities (Strigl, 2003). This approach aligns with the recent calls for more South-South cooperation with the Caribbean encouraging academic exchange and mobility among recent graduates (CCHE, 2010). Importantly, such networks could also help ensure that, when collaborating with foreign-based researchers bringing most of the funding, projects in conservation are also locally relevant (Baker et al., 2019; Malhado et al., 2014; Watkins and Donnelly, 2005). In parallel to this effort, it will be important to develop a regional agenda of strategic research priorities for the insular Caribbean – taking into account the important knowledge gaps in biodiversity and the need for technology transfer and scientific training – to help tackle shared threats to biodiversity while helping increase the global significance of locally-driven research.

We fully acknowledge that capacity building of this level will be a slow and expensive process (Heitor et al., 2014; Mammides

et al., 2016), but we contend that it is essential to achieve long-term effectiveness and sustainability of conservation efforts (Mammides et al., 2016). That said, short-term returns are also possible. For example, recent research supported by the Caribaea Initiative – a Caribbean-based NGO that funds and facilitates postgraduate training and networking opportunities for Caribbean conservation biology students – has already yielded valuable discoveries (Atherley et al., 2020; Cambrone et al., 2021; del Castillo Domínguez et al., 2021; Exantus et al., 2021; Rodriguez-Silva et al., 2020; Zhao et al., 2020). This locally-based approach is not a new one in the global arena (Mammides et al., 2016). It also aligns with previous findings that even small increases in investment in local research capacity in the Global South can provide quick and efficient returns (Holmgren and Schnitzer, 2004), particularly if such investments are in subdisciplines underpinning biodiversity conservation (Livingston et al., 2016). In the short- to medium-term, an important fraction of this highly skilled Caribbean-based workforce could be absorbed by local environmental NGOs and consultancy firms assisting local and regional governments in operationalizing international agreements and policy instruments protecting biodiversity (e.g. Aichi Biodiversity Targets) and promoting sustainable development (e.g. 2030 Agenda for Sustainable Development).

Our results are a call to action to change the status quo in biodiversity research in one of the most biodiversity-rich regions of the world. This will require explicit diversity, equity and inclusion policies by international funding bodies, research teams, and scientific publishers and substantial funding (see Table S2 in Supplementary material for further details and additional proposed measures). We suggest that such funding should come from diverse sources, including, notably, Caribbean governments, which need to be more policy-committed towards these efforts (e.g. see Brazil in Barber et al., 2014), the private sector in the region (in particular the nature-based private sector that so heavily relies on ecosystem services), local and international NGOs, international research funding agencies, and the countries of the Global North, particularly those with a colonial past in the region.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.pecon.2021.07.006>.

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