The cost of being a non-native English speaker in science

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Abstract

The use of English as the common language of science represents a major impediment to maximising the contribution of non-native English speakers to science. Yet few studies have quantified the consequences of language barriers on the career development of researchers who are non-native English speakers. Our survey demonstrates that non-native English speakers, especially early in their careers, spend more effort than native English speakers in conducting scientific activities, from reading and writing papers and preparing presentations in English, to disseminating research in multiple languages. Language barriers can also cause them not to attend, or give oral presentations at, international conferences conducted in English. We urge scientific communities to recognise and tackle these disadvantages to release the untapped potential of under-represented non-native English speakers in science.

Unlocking the potential of under-represented communities is one of the urgent challenges in science. Collaboration involving a diverse group of people can better solve problems (*1*) and deliver higher levels of scientific innovation (*2*) and impacts (*3*). Today, the need to tap into a diversity of people, views, knowledge systems, and solutions in order to successfully address global challenges, such as the biodiversity and climate crises (*4-6*), is being increasingly recognised, and there is a critical need to do so across multiple disciplines (*7-9*).

Increasing the diversity within scientific communities requires breaking down the barriers that impede the career development of under-represented groups of researchers, and one such barrier is rooted in language. Although the use of English as the common language of science has no doubt contributed to the advance of science, especially in the Global North (*10*), this benefit comes with considerable costs for those whose first language is not English (hereafter, non-native English speakers). Non-native English speakers, who constitute the majority of the world's population, face a number of challenges in conducting and communicating science in English, which inevitably impose an excessive burden on their career development in science. This issue is widely recognised (*11, 12*), yet scientific communities still desperately lack the concerted effort needed to reduce language barriers faced by non-native English speakers and promote equity in science.

The difficulties faced by non-native English speakers in conducting science, and how they translate to numerous disadvantages for career development, are still poorly understood. Earlier studies have

reported the experience and perception of language barriers in speakers of a single non-English language (*13*) or to certain types of scientific activities, such as paper writing (*14*), paper publication (*15*), and research dissemination (*16*). Attempts to assess the disadvantages of being non-native English speakers in science are emerging (e.g., *17, 18*). Nevertheless, to date, no published study has quantified how multiple aspects of language barriers concurrently affect the career development of speakers of different non-English languages, compared to native English speakers.

This study addresses this knowledge gap by first estimating the amount of effort (e.g., time and financial cost) required by individual researchers in conducting a variety of scientific activities in English. We compare the estimated amount of effort between researchers from countries with different linguistic and economic backgrounds, with the aim to quantify the multiple disadvantages faced by non-native English speakers practising science.

We conducted an online survey of a total of 908 researchers in environmental sciences who have published at least one first-authored peer-reviewed paper in English, with one of the following eight nationalities: Bangladeshi (n = 106), Bolivian (100), British (112), Japanese (294), Nepali (82), Nigerian (40), Spanish (108), and Ukrainian (66) (see more details including their demographic information in Table S1). These nationalities are stratified by the level of each country's English proficiency (based on the English Proficiency Index (*19*)) and income (based on the World Bank list of economies (*20*)): Bangladeshi, Nepali (low English proficiency and lower-middle income), Japanese (low English proficiency and high income), Bolivian, Ukrainian (moderate English proficiency and lower-middle income), Spanish (moderate English proficiency and high income), Nigerian (English as an official language and lower-middle income), and British (English as an official language and high income). The survey asks participants about the amount of effort needed to conduct five categories of scientific activities: paper reading, writing, publication, and dissemination, and participation in conferences (see **Materials and Methods** for more detail, and Supplementary Text S1 for the survey itself).

The results unveiled profound disadvantages for non-native English speakers in conducting all scientific activities surveyed. First, non-native English speakers require more time to read an English-language paper—a requisite for obtaining necessary knowledge in research (Fig. 1A, Table S2). In a comparison among researchers who have published only one English-language paper, non-native English speakers of moderate English proficiency nationalities spend a median of 46.64% (2.5 – 97.5 percentiles: 18.98 – 78.11%) more time, and those of low English proficiency nationalities spend a

median of 90.82% (60.58 – 125.40%) more time reading an English-language paper, than native English speakers do (Figs. 1A and S1). This disadvantage is found even in mid- and late-career researchers, especially those of low English proficiency nationalities (Figs. 1A and S1). Importantly, in a comparison of the time needed to read a paper written in their first language, non-native English speakers were shown to need less time than native English speakers (Fig. 1B, Table S3), showing that the above disadvantage arises from the need to read in English, not in their first languages.

Similarly, non-native English speakers need more time to write a paper in English, than their native English speaker peers, at an early career stage (Fig. 1C, Table S4). In a comparison of researchers who have published only one English-language paper, non-native English speakers of moderate English proficiency nationalities spend a median 50.64% (2.5 - 97.5 percentiles: 31.12 - 52.56%) more time, and those of low English proficiency nationalities spend 29.80% (6.57 – 59.32%) more time writing a paper in English, than native English speakers do (Figs. 1C and S2). This disadvantage is not found in those at a later career stage (Fig. S2). Again, non-native English speakers need less time to write a paper in their first languages, than native English speakers do (Fig. 1D, Table S5). This signifies that the need to write in English, not in their first languages, poses a disadvantage to non-native English speakers.

Non-native English speakers also require more effort than native English speakers for the English proofreading of their papers. Apart from late-career researchers of moderate English proficiency nationalities, non-native English speakers ask someone to proofread their English for, on average, 75% or more of their papers, while most native English speakers do this in less than half of their papers (Fig. S3, Table S6). Non-native English speakers of moderate English proficiency nationalities tend to ask someone to proofread their English as a favour (Fig. 1E, Table S7), while those of a low English proficiency nationality and high income level (i.e., Japanese in our study sample) tend to use a professional English editing service (Fig 1F, Table S8). Non-native English speakers of low English proficiency nationalities and lower-middle income level neither ask someone to proofread their English as a favour nor use a paid service for most of their papers (Fig. 1E, F).

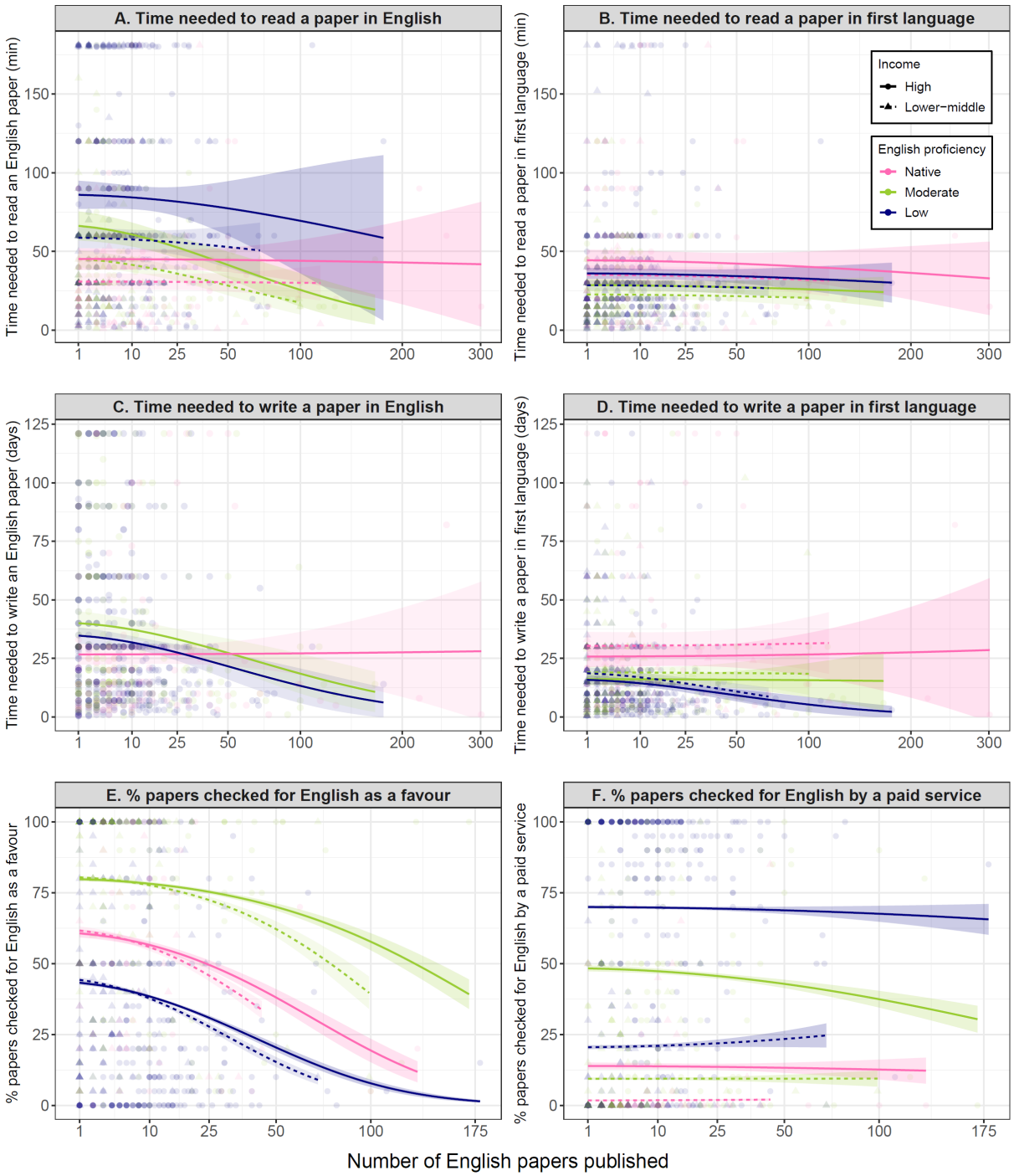


Fig. 1. Language barriers in paper reading and writing. (A) Minutes taken to read and understand the content of the most recent English-language research article each participant read in their field. (B) Minutes it would take to fully read and understand the same paper in one's first language. (C) Number of days (assuming seven hours being spent per day) taken to write the first draft of each participant's latest first-authored paper in English. (D) Number of days that would be taken to write the first draft of the same paper in their first language. (E) Percentage of papers where English writing was checked by someone as a favour. (F) Percentage of papers where English writing was checked by a professional

service. The regression lines (with 95% confidence intervals as shaded areas) represent the estimated relationship with the number of English-language papers published, based on the results shown in Tables S2-5 and S7-8 (income level was not significant and thus not shown in (C)).

Non-native English speakers, especially those of low English proficiency nationalities, are more likely to have their papers rejected by journals due to English writing, compared to native English speakers (Fig. 2A, Table S9). For example, in a comparison of those who have published one English-language paper, 38.1% (31.6 – 44.5%) and 35.9% (30.5 – 41.3%) of the non-native English speakers of moderate and low English proficiency nationalities, respectively, have experienced paper rejection due to English writing, while only 14.4% of the native English speakers have, meaning that the frequency of language-related paper rejection is at least 2.5 times higher for non-native speakers. Similarly, non-native English speakers are more likely to be requested to improve their English writing during paper revision (Fig. 2B, Table S10). For example, 42.5% and 42.6% of the non-native English speakers of moderate and low English proficiency nationalities, respectively, compared to only 3.4% of the native English speaker population, report that they are often/most of the time/always requested to improve their English writing during paper revision. This equates to a 12.5 times higher frequency of language-related revisions for non-native English speakers.

Non-native English speakers spend more effort disseminating their research in multiple languages than native English speakers do, may it be through the publication of their work in non-English-language journals (Fig. S4), preparation of non-English-language abstracts of English-language papers (Fig. 2C, Table S11), or outreach activities in two or more languages (Fig. 2D, Table S12).

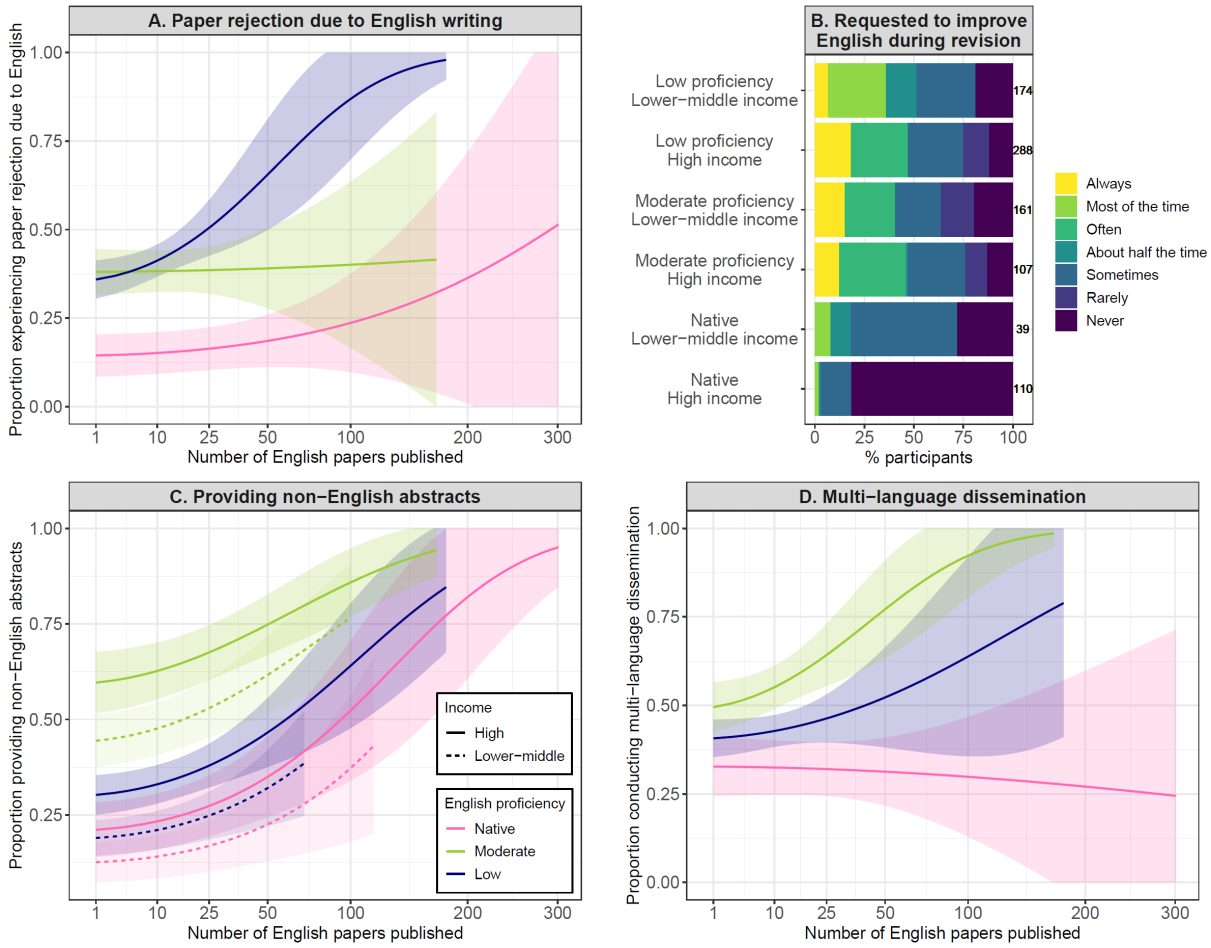
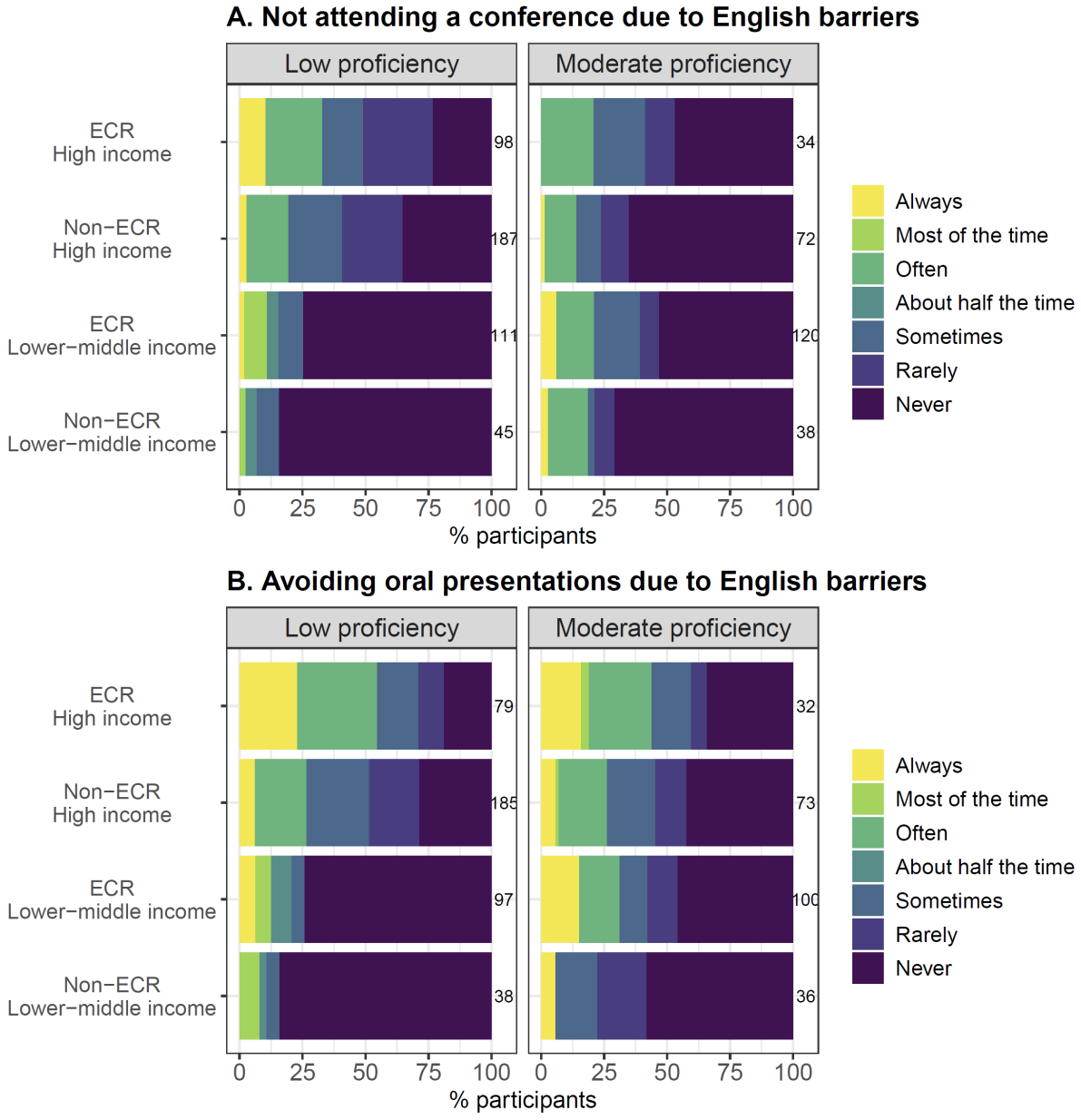


Fig. 2. Language barriers to paper publication and dissemination. (A) Proportion of researchers who have experienced rejection of a first-authored English-language paper due to English writing. (B) Frequency of being requested to improve English writing during the revision of first-authored English-language papers. (C) Proportion of researchers who have provided non-English-language abstracts of English-language papers. (D) Proportion of researchers who have disseminated English-language papers in other languages as well as English. The regression lines (with 95% confidence intervals as shaded areas) in (A), (C) and (D) represent the estimated relationship with the number of English-language papers published, based on the results shown in Tables S9, 11 and 12.

Language can also be a major barrier to non-native English speakers attending conferences. Approximately 30% of the early-career (defined as those who have published five or fewer English-language papers) non-native English speakers of high income nationalities (i.e., Japanese and Spanish combined) report that they often or always decide not to attend an English-language conference due to language barriers (Fig. 3A, Table S13). Similarly, about half of the early-career non-native English speakers of high income nationalities (Japanese and Spanish combined) often or always avoid oral

159 presentations due to language barriers (Fig. 3B, Table S14).



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161 **Fig. 3. Language barriers to participation in conferences.** The frequency of (A) not attending an
162 English-language conference, and (B) avoiding oral presentations at an English-language conference
163 due to the lack of confidence in English-language communication. An ECR (early-career researcher)
164 was defined as someone with five or fewer English-language papers. The numbers on the right of each
165 bar represent the sample size.

166

167 Even if they decide to give an oral presentation in English, non-native English speakers need much

more time to prepare the presentation, than native English speakers do; those of moderate and low English proficiency nationalities spend a median 93.73% (2.5 – 97.5 percentiles: 54.68 – 145.20%) and 38.02% (10.83 – 69.55%) more time, respectively, preparing an oral presentation in English than native English speakers do (Figs. 4A, Table S15). This disadvantage does not change with one's career level (Fig. S5) and, yet again, does not apply when preparing a presentation in one's first language. For example, non-native English speakers of low English proficiency nationalities even spend less time preparing a presentation in their first language, than native English speakers (Fig. 4B, Table S16). At conferences, non-native English speakers often struggle to explain their work in English. This tendency is particularly noticeable in early-career non-native English speakers of low English proficiency nationalities, with over 65% reporting that they often or always find it difficult to explain their work confidently in English (Fig. 4C, Table S17).

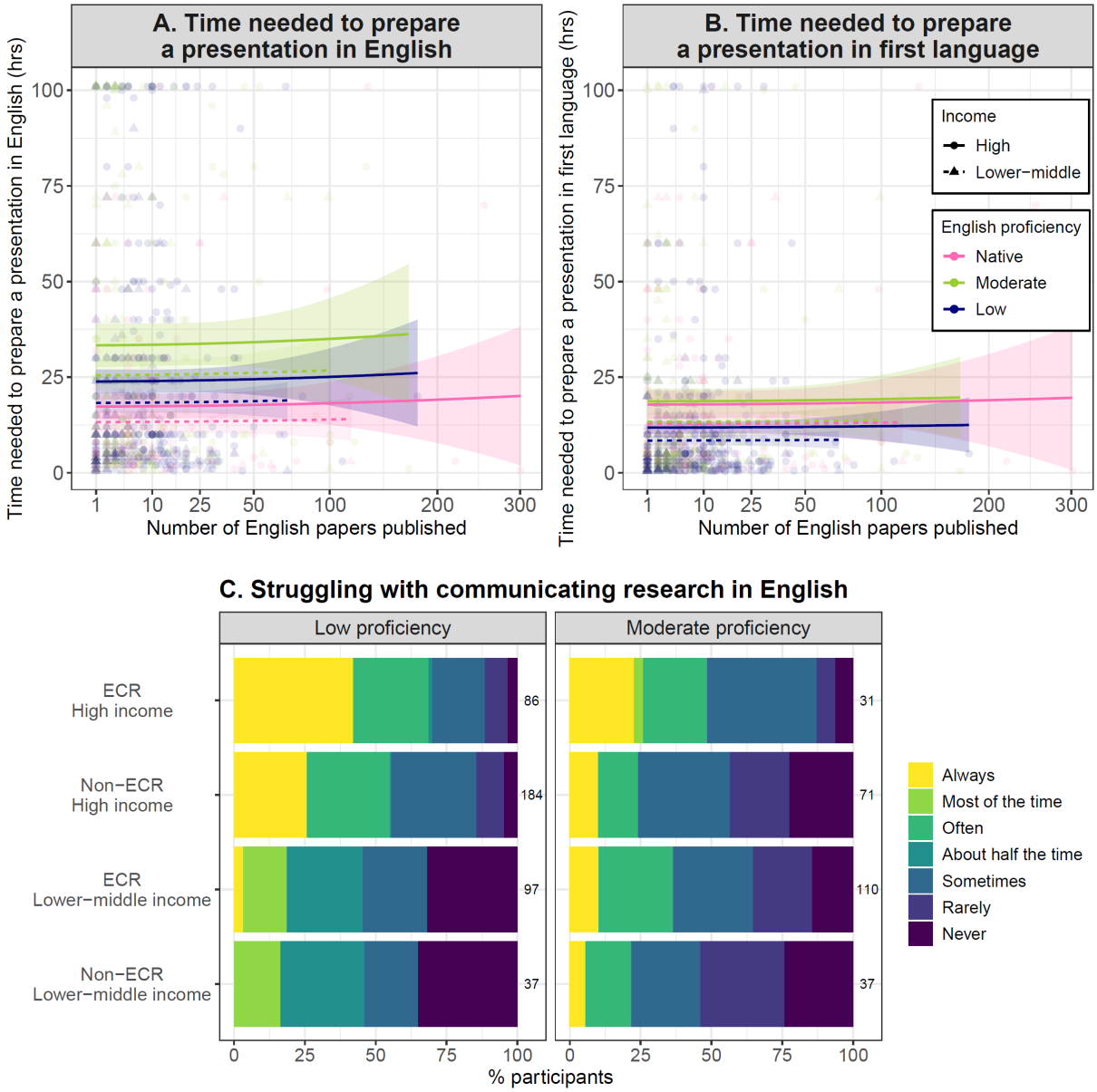

Fig. 4. Language barriers to preparing and conducting presentations in English. (A) Number of hours needed to prepare and practice an oral presentation in English. (B) Number of hours that would be needed to prepare and practice the same oral presentation in one's first language. (C) Frequency of not being able to explain research confidently during a presentation due to English-language barriers. The regression lines (with 95% confidence intervals as shaded areas) in (A) and (B) represent the estimated relationship with the number of English-language papers published, based on the results shown in Tables S15 and 16. In (C) an ECR (early-career researcher) was defined as someone with five or fewer English-language papers published so far. The numbers on the right of each bar represent the sample size.

This study illustrates how a series of language barriers to conducting different scientific activities multiply to pose a profound disadvantage to non-native English speakers in the development of their scientific careers (Fig. S6). Imagine being a PhD student whose first language is not English. Compared to a fellow student who is a native English speaker, you would need considerably more time, or financial cost, to understand every single English-language paper you read (causing you to spend up to 19.5 more days per year. See Fig. S1 for the calculation), to write your thesis chapters in English, and to polish the English writing before submitting your manuscripts to journals. You would also struggle with paper publication, as your papers will be rejected more often, and be subject to revisions based on the written English. Following the publication of your papers, you would need to make an extra effort for dissemination, as you will be doing this in English as well as your own language(s). You will also find yourself hesitating to attend an international conference, or give an oral presentation, ending up losing opportunities to develop an international network. When you do decide to give an oral presentation, you would again need more time than native English speakers for its preparation, after which you would still be frustrated as you are unable to present your work as effectively in English as you would in your first language. What is more, all of these barriers will continue to get in your way as long as you remain in a research career.

Given all of these disadvantages, all else being equal, the apparent scientific productivity of non-native English speakers would undoubtedly be much lower than that of native English speakers. These disadvantages inevitably lead to a tremendous inequality in the development of scientific careers between native and non-native English speakers. Furthermore, at a bigger scale, one clear consequence of this inequality is the loss of opportunity for scientific communities to incorporate a good proportion of researchers and associated knowledge in the early stages of their careers, partly because their first language happens to be one other than English. This may be reflected in our observation that some disadvantages seemed to disappear in late-career researchers (Figs. S1 and S2). We suspect this could be due to survivorship bias; only those non-native English speakers who have managed to conduct science in English as efficiently as native English speakers may have remained in a research career and thus been the dominant group among the experienced researchers who participated in this survey.

The under-use of professional English editing services by those of lower income nationalities, presumably due to the lack of funding, indicates that disadvantages for non-native English speakers could be amplified by a country's and individual's low income level. Language barriers to some scientific activities, such as reading papers (Fig. 1A), preparing oral presentations (Fig. 4A), and

attending and presenting at conferences (Figs. 3A-B, 4C), appear to be less severe for those of lower income nationalities. This might again be explained by survivorship bias. Apart from those languages spoken in high income countries, such as Spanish and Japanese, few non-English languages have an up-to-date lexicon of scientific terms, creating a much higher need for their speakers to receive scientific education in English (*21*). In the low-income countries, only those who can afford to receive such English-language education may have been able to become researchers and participate in our survey.

This study is still likely to have underestimated the severity of the disadvantages faced by non-native English speakers. For example, we did not quantify the immense mental stress associated with all the extra time, cost, effort and lost opportunities caused by language barriers, which could further exacerbate the already high risk of mental health issues in students and early-career researchers (*22*). The survey participants are most likely to be those who are currently active in research, and thus the survey has likely excluded those who have dropped out due to language barriers. Other biases in survey participants may also exist (see Limitations in **Materials and Methods** for discussion).

To date the task of overcoming language barriers has largely been left to non-native English speakers' efforts and their investment in ways of improving their English skills. However, the magnitude of the disadvantage, quantified in this study, seems far beyond the level that can be overcome with individuals' efforts. The use of machine translation, often viewed as a panacea for this issue, is not sufficient to remove all the language-related disadvantages, as is reflected in the relatively low usage rate in all countries surveyed (Fig. S7). We are urgently in need of a concerted effort, at institutional and societal levels, to minimise the disadvantages for non-native English speakers. Examples include providing language support to paper authors and conference participants, and explicitly taking into account those disadvantages when evaluating scientific outcomes from non-native English speakers (*23*) (see Table S18 for proposed solutions).

The inequality faced by non-native English speakers due to language barriers can be a major reason for the current underrepresentation of non-native English speakers in global scientific activities (*24*). One comment from a survey participant caught our eyes:

If it wasn't for the language barrier, I could have made a much greater contribution to the advance of ecology and biodiversity conservation. (female participant from Japan in the 40-50 age bracket)

Non-native English speakers constitute 95% of the world population (*25*). Imagine how many non-

native English speakers around the world and over time have been frustrated, just like this participant, because they are unable to contribute to the advance of science to the best of their abilities. Think how many potential contributors scientific communities have failed to bring onboard due to language barriers. Given the multitude of pressing challenges facing humanity and this planet, surely, we cannot afford to miss contributions from such a promising, much needed, yet currently untapped source of researchers.

Materials and Methods

The aim of the survey was to (i) quantify the amount of effort required by individual researchers to conduct five types of scientific activities in English and their first language: paper reading, writing, publication, and dissemination, and participation in conferences, and (ii) compare the estimated amount of effort between researchers with different linguistic and economic backgrounds.

Target participants

For the comparison between researchers with different linguistic and economic backgrounds, we selected eight nationalities: Bangladeshi, Bolivian, British, Japanese, Nepali, Nigerian, Spanish, and Ukrainian. These nationalities were stratified by the levels of each country's English proficiency (based on the English Proficiency Index (*19*)) and income (based on the World Bank list of economies (*20*)): Bangladeshi, Nepali (low English proficiency and lower-middle income), Japanese (low English proficiency and high income), Bolivian, Ukrainian (moderate English proficiency and lower-middle income), Spanish (moderate English proficiency and high income), Nigerian (English as an official language and lower-middle income), and British (English as an official language and high income). We focused on English proficiency and income level based on our hypothesis that the amount of effort needed to conduct scientific activities in English would be higher in non-native English speakers from countries with lower English proficiency and income level.

Note that the level of countries' English proficiency does not necessarily reflect the level of each participant's English proficiency. However, the level of countries' English proficiency was significantly related to two of the three other measures of participants' experience in English communication: the percentage of time spent speaking English in a day and the number of years spent living in countries where English is the first language (Figs. S8-10). This supports the use of countries' English proficiency as a crude measure of participants' English proficiency.

Countries' income levels do not necessarily reflect each participant's socio-economic level either. This study is thus not able to assess the effect of individuals' socio-economic backgrounds.

The survey was targeted at anyone at any career level and of any profession who has the selected countries' nationality and has published at least one first-authored peer-reviewed English-language paper in ecology, evolutionary biology, conservation biology or related disciplines.

Questionnaire survey

The survey (provided in Supplementary Text S1) consists of six sections. The first section (Q1.1-1.2) is about participants' first language (defined as "the language(s) you learnt to speak at home as a child") and nationality; this information was used to filter for eligible participants. The second section (Q2.1-2.7) comprises questions on background information including measures of English proficiency; these were used to account for factors that may affect the answers to the other questions in the survey during analysis, and to justify the use of countries' English proficiency in the analysis. The third section (Q3.1-3.7) includes questions on participants' experience of language barriers when writing papers in English. The fourth section (Q4.1-4.5) asks about participants' experience of language barriers in paper publication and dissemination. The fifth section (Q5.1-5.3) is about the consequences of language barriers to paper reading in English, and the sixth section (Q6.1-6.6) asks how language barriers might have affected participants' experiences around the attendance of scientific conferences. The survey also allowed participants to give comments on the survey as well as general feedback on the project.

To allow participants to estimate the length of time required to do each scientific activity as accurately as possible, we asked participants to provide data on actual experiences, i.e., how long it took them to write the latest paper that they wrote (Q3.3), read the latest paper that they read (Q5.1) and prepare the latest oral presentation that they gave (Q6.4) in English. We also asked non-native English speakers to estimate the length of time that would be required to write the same paper (Q3.4), read the same paper (Q5.2) and prepare the same presentation (Q6.5) but in their first language. See Limitations for a discussion on the potential consequences of this approach for deriving conclusions. When asking frequency, we used a five-point Likert scale: Always, Often, Sometimes, Rarely, or Never.

To maximise the response rate, the survey was translated into the relevant languages for each nationality (Bangla for Bangladeshi translated by SC, Japanese for Japanese by TA, Nepali for Nepali by KP, Spanish for Bolivian and Spanish by VB-E, and Ukrainian for Ukrainian by MG), and

implemented as a separate online survey for each nationality on Qualtrics. We created a unique link and QR code for each country, which was used for distribution described below.

The survey was conducted between June and October 2021 in accordance with the University of Queensland's Institutional Human Research Ethics Approval (approval number 2021/HE000566). All participants were at least 18 years old and provided consent indicating their agreement to participate in the survey. The Participant Information Sheet clarified the voluntary nature of participation, the aims of the research, how the data would be used and that all data would be confidential.

Survey distribution

We first identified coordinators (hereafter referred to as country coordinators) for each of the eight selected countries, who (i) is a native speaker of the official language of the country and (ii) has a good network among researchers in the relevant disciplines in the country. All country coordinators were involved in this study as coauthors (TA for Japan, IB for Nigeria, SC for Bangladesh, MG for Ukraine, JDG-T for Spain, FM-C for Bolivia, KP for Nepal and RW for the UK). Country coordinators aimed to collect responses to the survey from at least 100 participants in each country. We tried to distribute the survey in as unbiased a way as possible. To achieve this we adopted, in principle, one or all of the following four methods of survey distribution within each country, based on discussions with each country's coordinator on which method(s) might be the best for that country:

- Distribute the survey through major mailing list(s) for researchers in relevant disciplines.
- Ask academic societies of relevant disciplines to distribute the survey to their members.
- Identify up to ten universities and institutions with relevant departments, schools or divisions within the country and ask them to distribute the survey to their affiliated researchers.
- Identify researchers who have published an English-language paper in a relevant discipline and are affiliated to an institution in the country on literature search systems and directly send the survey to them via email.

We avoided using our personal networks (including personal social media accounts) to disseminate the survey as much as possible, in order to reduce potential biases in participant recruitment (but see exceptions for Bangladesh below). The detailed method of survey distribution in each country is described below (all dates refer to 2021).

Bangladesh

In Bangladesh we could not find any relevant mailing lists. Academic societies exist but early-career

researchers do not necessarily belong to those societies, and we thus decided not to distribute the survey through academic societies either. Instead, the survey was distributed by directly contacting seven universities and a total of 232 individual researchers identified on Google Scholar and Facebook.

22nd and 27th June: Shared the survey on the country coordinator's personal Facebook account.

14th – 18th July: Contacted representatives at four major universities (University of Dhaka, Jahangirnagar University, Pabna University of Science and Technology, and Noakhali Science and Technology University) and asked them to share the survey within their relevant departments.

25th July: Re-contacted representatives at three universities (University of Dhaka, Jagannath University, and Noakhali Science and Technology University) and asked them to share the survey within their relevant departments. Also emailed a professor at the University of Dhaka to share the survey with colleagues, who also shared it with many other academics in the country.

31 July: Re-contacted a representative at the University of Dhaka and newly contacted representatives at three more universities (Sher-e-Bangla Agricultural University, Bangladesh Agricultural University, and Chittagang University) and asked them to share the survey within their relevant departments.

8th August: Re-shared the survey on the country coordinator's personal Facebook and Twitter account.

12th September: Directly emailed the survey to the top 100 Bangladeshi researchers identified on Google Scholar (searched with (conservation OR ecology OR evolution) AND Bangladesh).

22nd September – 15th October: Contacted 120 researchers in relevant disciplines identified on Facebook.

28th October: Shared the survey on the country coordinator's personal Facebook and LinkedIn accounts, and also contacted 12 researchers while sending a reminder to those who were already contacted.

Bolivia

In Bolivia the survey was distributed through a major mailing list and by contacting four societies, five universities, four museums/herbaria, and a total of 72 individual researchers identified on the Web of

Science.

29th June:	Shared the survey on a major mailing list for biologists and ecologists in Bolivia. Reminders sent once within June and another in July. The survey was also sent to the Organization of Women in Science Bolivia, the Bolivian Association of Ornithologists, the Bolivian Association of Mammalogists, and the Bolivian Society of Entomologists, for sharing on their mailing lists.
1st July:	Contacted the Heads of the Departments of Biology, Zoology, Botany and Ecology in all five universities that have a science department in Bolivia (Universidad Mayor de San Andrés, Universidad Amazónica de Pando, Universidad Mayor Gabriel Rene Moreno, Universidad Mayor de San Simón, and Universidad San Francisco Xavier de Chuquisaca) and the four major museums/herbaria in Bolivia (Colección Boliviana de Fauna, Herbario Nacional de Bolivia, Museo de Historia Natural Noel Kempff Mercado, and Museo Nacional Martin Cardenas), and asked them to share the survey within their departments. Sent reminders to them on the 26th July.
16th September:	Searches were conducted on Web of Science (using all databases) with: ALL=((conservation OR ecolog* OR evolution*) AND (Bolivia)). 3,715 studies were returned from the search, from which 72 first authors who seemed to be Bolivians were identified. The survey was directly shared with the 72 authors via email. For those authors who were not accessible through the email addresses on the papers, the country coordinator looked for their new contact addresses (on ORCID and some other platforms) and if found, used the new addresses to contact them.

Japan

In Japan the survey was shared via two major mailing lists.

9th June:	Shared the survey on the two major mailing lists for ecologists (*jeconet*, with 3,500 users as of 2014) and evolutionary biologists (*evolve*, with 2,500 users as of 2016) in Japan.
23rd June:	Sent a follow-up email to the same two mailing lists.

Nepal

In Nepal the survey was shared with five societies and five universities.

2nd July:	Asked the Nepal Environment Society, the Environmental Graduates in

		Himalaya, the Society for Conservation Biology Nepal Chapter, the Botanical Society of Nepal, and the Zoological Society of Nepal (altogether these societies have more than 600 members) to share the survey on their mailing lists.
	27th July:	Sent reminders to those who were contacted above.
	5th September:	Contacted the Heads of Departments of five universities that have programmes in biodiversity conservation and natural sciences (Kathmandu University, Tribhuvan University, Pokhara University, Mid-western University and Agriculture and Forestry University) over the phone and asked them to share the survey within their departments.
	20th September:	Sent reminders to those universities.

Nigeria

In Nigeria the survey was distributed by contacting three relevant societies, three institutes with relevant departments, five universities (from five of the six geopolitical zones in Nigeria), and a total of 54 individual researchers identified on Google Scholar.

	21st June:	Shared the survey with the Nigerian Tropical Biology Association alumni group, scientists at the National Center for Genetic Resources and Biotechnology, and researchers at the Department of Zoology, University of Lagos.
	22nd and 23rd June:	Shared the survey with scientists at the Sheda Science and Technology Complex.
	6th July:	Contacted the assistant secretary of the Zoological Society of Nigeria, who shared the survey with all of the society's members (approximately 400 people).
	8th July:	Shared the survey with 36 faculties across the Departments of Botany, Forest Resources Management, Wildlife and Ecotourism, Chemistry, Geography, and Geology at the University of Ibadan.
	10th July:	Shared the survey on Whatsapp among all scientists of the Cocoa Research Institute of Nigeria, a federal government institution with over 200 research staff.
	14th July:	Sent reminders to the Nigerian Tropical Biology Association alumni group, scientists at the National Center for Genetic Resources and Biotechnology, and researchers at the Department of Zoology, University of Lagos.

12th September:	Shared the survey with 60 faculty members of the Adekule Ajasin University and one at the Abubakar Tafawa Balewa University.
14th October:	Shared the survey with 63 faculty members of Ahmadu Bello University.
18th October:	Shared the survey with 173 members of the Society for Conservation Biology Nigerian Chapter, and 54 authors identified through searches on Google Scholar using: "(conservation OR ecology OR evolution) AND Nigeria".

Spain

In Spain the survey was shared with five societies, 19 universities and a museum. We chose one to four universities with a strong biology department from each of the nine, out of the 17, autonomous communities of Spain, so that the selected universities are geographically scattered.

21st June:	Asked the Limnological Society, the Society of Terrestrial Ecologists, the Society for Evolutionary Biology, the Society for Biochemistry and Molecular Biology, and the Society for Cellular Biology to share the survey with their members via their channels.
5th July:	Sent the first reminder to the five societies above.
30th August:	Sent a second reminder to the five societies. Asked the biology/science departments of nine universities across the country to share the survey within their departments: Universidad de Barcelona, Universidad Autónoma de Barcelona, Universidad de Girona, Universidad Complutense de Madrid, Universidad de Sevilla, Universidad de Valencia, Universidad de Cádiz, Universidad de Murcia, and Universidad del País Vasco.
13th September:	Sent a third reminder to the first five societies, and the first reminder to the nine additional universities.
4th October:	Sent a fourth reminder to the five societies, and a second reminder to the nine universities. Asked ten additional universities and a museum to share the survey within their networks: Universidad del rey Juan Carlos, Universidad Autónoma de Madrid, Universidad de Salamanca, Universidad de Huelva, Universidad de Málaga, Universidad de Burgos, Universidad de León, Universidad de Castilla y La Mancha, Universidad de Alicante, Universidad de Zaragoza, and Madrid's Museum of Natural Sciences.
18th October:	Sent reminders to the five societies, 19 universities and the museum.

25th October: Sent reminders to the five societies, 19 universities and the museum.

Ukraine

In Ukraine the survey was shared through ten universities, three institutes, three Facebook groups, and a total of 139 individual researchers identified on the Web of Science, conference abstracts and Ukrainian journals.

29th June: Shared the survey among employees of the State Museum of Natural History (Lviv); also posted on the Facebook group Flora of Ukraine by the museum administrator. Asked the Institute of Ecology of the Carpathians, NASU (Lviv) to share the survey within their network.

22nd July: Asked the I.I. Schmalhausen Institute of Zoology of the National Academy of Sciences of Ukraine (NASU) (Kyiv) to share the survey within their network.

13th September: Shared the survey with all researchers at the Institute of Marine Biology, NASU (Odesa), and 139 researchers identified on the Web of Science (using keywords: All=((conservation OR ecolog* OR evolution*) AND (Ukraine))) and by searching for conference abstracts on Google (using keywords: “еволюційна біологія конференція”, “охорона природи конференція”, or “екологія конференція”).

14th September: Asked biology/ecology departments of ten universities (Khmelnytsky National University, Petro Mohyla Black Sea National University, Sumy State University, National University of Water and Environmental Engineering, National University of Life and Environmental Sciences of Ukraine, Poltava National Agricultural University, Ukrainian National Forestry University, Ivano-Frankivsk National Technical University of Oil and Gas, Chernivtsi National University, and National Museum of Chernivtsi National University) to share the survey within their network.

27th September: Sent reminders to all individual researchers who were contacted on 13th September.

11th October: Sent reminders to all individual researchers who were previously contacted.

11th October: Shared the survey in the Facebook group Ukrainian Botanical Group.

13th October: Shared the survey in the Facebook group Ukrainian Scientists Worldwide.

United Kingdom

In the UK the survey was disseminated through three societies/professional bodies, one research institute, and 20 universities.

- British Ecological Society (BES)

10th June: Asked to disseminate the survey via their channels.

25th Aug: Sent a reminder.

The BES journals' twitter accounts tweeted about the survey:

7th July and 7th September @MethodsEcolEvol (26.3k followers)

13th July and 13th September @FunEcology (21.6k followers)

14th July and 7th September @jecology (30.7k followers)

9th July and 7th September @JAppliedEcology (31.4k followers)

7th July and 7th September @AER_ESE_BES (2.1k followers)

7th July and 7th September @AnimalEcology (22.7k followers)

7th July and 15th September @PaN_BES (4.6k followers)

- Royal Society of Biology (RSB)

10th June: Asked to disseminate the survey via their channels.

25th June: The survey was shared in their Science Policy Newsletter, which goes out to roughly 26,000 people, most in the UK.

25th Aug: Sent a reminder.

10th September: The survey was shared again in their Science Policy Newsletter.

- Chartered Institute of Ecology and Environmental Management (CIEEM)

10th June: Asked to disseminate the survey via their channels.

25th August: Sent a reminder

- Centre for Ecology and Hydrology (CEH)

10th June: Asked to disseminate the survey via their channels.

1st September: CEH tweeted about the survey @UK_CEH (39.6k followers)

13th September: CEH tweeted about the survey @UK_CEH

- Universities

1st September: Selected and emailed 10 universities to reach out and request to disseminate the survey internally. Using the 2022 'The Complete University Guide' rankings for Biological Sciences (which includes, but is not limited to: Biological Sciences, Biology, Ecology, Marine Biology, Cell Biology, Microbiology, Plant Sciences, Zoology, Genetics, Biochemistry, Applied Biology, Evolution), every 10th institution within the top 100 universities was selected:

#1 University of Cambridge, School of the Biological Sciences

#10 University of Glasgow, School of Life Sciences

#20 University of Leeds, Faculty of Biological Sciences

#29 University of Nottingham, School of Life Sciences (#30 University of Sunderland was not selected as not appropriate)

#39 University of Kent, Durrell Institute of Conservation and Ecology (#40 Glasgow Caledonian University was not selected as not appropriate)

#49 University of Plymouth, School of Biological and Marine Sciences (#50 Keele University was not selected as not appropriate)

#60 University of Lincoln, School of Life Sciences

#70 University of Northampton

#80 Liverpool John Moores University, School of Biological and Environmental Sciences

#90 University of Derby, School of Built and Natural Environment

13th September: Sent a reminder to all university departments.

5th October: Sent a reminder to all university departments.

5th October: Reached out to a further 10 universities as follows:

#2 = University of Oxford

#11 = University of Bristol

#21 = University of Bath

#31 = Swansea University

#41 = Edinburgh Napier University

#51 = University of Essex

#61 = Aberystwyth University

#72 = Bangor University (#71 University of Westminster was not selected as not appropriate)

#81 = University of Brighton

#91 = University of Suffolk

Limitations

The limitations of our survey include: (i) relatively small sample size, (ii) potential bias in participant recruitment, and (iii) difficulties in estimating the length of time taken to conduct scientific activities in different languages.

Despite the considerable effort we put in in distributing the survey at 71 universities, 12 institutes, and 23 societies, on three mailing lists, and with 497 individual researchers across eight countries, the sample size of this study (908, ranging from 67 to 292 per language) is not necessarily large. This may have caused the lack of power in our analyses, which could explain the non-significant effect of income level in some analyses.

Although we tried to recruit survey participants in as unbiased a way as possible (see Survey distribution), we acknowledge that the recruited participants are likely to represent non-random samples of the entire eligible population. For example, survey participants are most likely to be active researchers, and thus the survey likely excludes those who have already left their research careers due to language barriers. Our survey also excluded those who have never published a first-authored English-language paper. This could lead to an underestimation of the actual severity of the language barriers experienced by the entire population of non-native English speakers. We also recorded five potential covariates that can affect the amount of effort required to conduct scientific activities in English: age, gender, discipline, the number of years in research, and the number of English-language publications. Age, gender, discipline and the number of years in research were all correlated with the number of English-language publications (see Analyses for more detail). Therefore, we used the number of English-language publications as a covariate in all analyses, to account for the effect of these covariates.

It is admittedly difficult for participants to estimate the exact length of time taken, or would take, to write a paper, read a paper, or prepare an oral presentation in English and in their first languages. To allow participants to provide as accurate an estimate as possible, we asked them the actual time taken to, for example, write the most recent paper that they wrote in English, rather than the time that they *think* is required to write an imaginary paper, as it is normally easier and more accurate to report the most recent experience (recall bias, see e.g., (*26*)). There is no reason to believe that non-native English speakers consistently over-estimate the actual length of time they have spent on scientific activities. We rather expect that the difficulty in estimating the length of time taken to conduct scientific activities can affect precision, as is reflected in large variation within each group of the English proficiency-economic level combinations. As we asked the participants to answer based on actual experiences, the reported length of time taken to, for example, write a paper would also have depended on the varying length of the paper. Nevertheless, again, there is no reason to believe that papers written by non-native English speakers are consistently longer than those written by native

English speakers. We thus do not believe that these issues affect the main conclusion of this study. That said, the reported length of time it would take to conduct scientific activities in their first language is not based on the participants' actual experience and thus needs to be interpreted with care.

Analyses

In the analyses, we only used data on participants whose nationalities were one of the eight target nationalities and whose first language was one of the six target languages. In all the analyses we aimed to test whether the amount of effort required for scientific activities, or the frequency of facing language barriers in science, differs for participants depending on their native country's level of English proficiency and economy, while accounting for the effect of covariates.

As covariates, we considered the following five variables: age, gender, discipline, the number of years in research, and the number of English-language publications. We first tested correlations between the five covariates. Age and the number of years in research were both highly correlated with the number of English-language publications (Spearman's rank correlation coefficient = 0.58 for age and 0.64 for the number of years in research). There was also a highly significant relationship between gender and the number of English-language publications (Kruskal-Wallis chi-squared = 68.37, $p < 1.42 \times 10^{-15}$) and between disciplines and the number of English-language publications (Kruskal-Wallis chi-squared = 29.45, $p < 6.35 \times 10^{-6}$). Thus we decided to only use the number of English-language publications as a covariate in the following analyses.

We used three types of models depending on the type of the response variables:

Generalised linear models with a negative binomial distribution for

- The number of minutes taken to read and understand the last English-language original article each participant read in their field.
- The number of minutes it would take to read and understand the same paper but in their first language.
- The number of days taken to write the first draft of each participant's latest first-authored paper in English.
- The number of days it would have taken to write the first draft of each participant's latest first-authored paper in their first language.
- The number of hours taken to prepare and practice an oral presentation in English.
- The number of hours it would take to prepare and practice the same oral presentation in their first language.

Generalised linear models with a binomial distribution for

- The percentage of papers where English writing was checked either by someone as a favour or by a paid service.
- The percentage of papers where English writing was checked by someone as a favour.
- The percentage of papers where English writing was checked by a paid service.
- The experience of a first-authored English-language paper being rejected due to English writing.
- The experience of providing a non-English-language abstract of English-language papers.
- The experience of conducting the dissemination of English-language papers in other language(s) as well as English.

Cumulative link models for

- The frequency of being requested to improve English writing in the revision of first-authored English-language papers.
- The frequency of not attending an English-language conference due to the lack of confidence in English-language communication.
- The frequency of avoiding giving oral presentations at an English-language conference due to the lack of confidence in English-language communication.
- The frequency of not being able to explain one's own research confidently during a presentation due to English-language barriers.

In all models we used three explanatory variables: a country's English language proficiency (English native as the reference category, moderate (the reference category in analyses not including English natives), and low), a country's income level (high as the reference category, and lower-middle), and the number of English-language publications, as well as two interactions: English language proficiency and the number of English-language publications, and income level and the number of English-language publications. We first tested whether the two interactions were significant using the likelihood-ratio test, and excluded any non-significant interactions. If any interaction was excluded, we again tested whether the explanatory variables that were involved in the interaction(s) were significant using the likelihood-ratio test, and excluded any non-significant variables to determine the final model. We interpreted the results derived from the final models. In a few analyses (shown in Tables S3, S15 and S16), however, even non-significant variables were retained in the final models to enable comparisons with results from other associated analyses.

All analyses were conducted in R version 4.1.2 (*27*). We also used the following R packages:

651 tidyverse (*28*), MASS (*29*), lmtest (*30*), janitor (*31*), corrplot (*32*), ordinal (*33*), and gridExtra (*34*).

652

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Competing interests

Authors declare that they have no competing interests.

Data and materials availability

We are unable to make data on participants' responses to the survey questions publicly available, as per our agreement with the University of Queensland Ethics office and due to the confidentiality of the data. All codes used in the analysis are available at: http://doi.org/10.17605/OSF.IO/Y94ZT.

Supplementary Materials

Supplementary Tables

Table S1. Survey participants by nationality and first language. The gender composition of the participants was 339 female, 556 male and 13 participants in other categories, with the median age of 39 (range: 18 - 77) years old and median 13 (range: 1 - 55) years of experience in research.

Nationality\First language	Bangla	English	Japanese	Nepali	Spanish	Ukrainian
Bangladeshi	106					
Bolivian					100	
British		112				
Japanese	1	1	292			
Nepali		1		80	1	
Nigerian		40				
Spanish					107	1
Ukrainian						66
Total	107	154	292	80	208	67

Table S2. Results of a generalised linear model (with a negative binomial distribution) of factors explaining variations in the number of minutes taken to read and understand the entire content of the last English-language original article each participant read in their field. The reference category for English proficiency and Income level was English native and High income, respectively.

Variables in the final model	**Coefficients**	**Standard errors**	**z**	**p**
Intercept	3.81	0.078		
Low English proficiency	0.64	0.090	7.14	9.29×10^{-13}
Moderate English proficiency	0.39	0.099	3.95	7.79×10^{-5}
Number of English papers published	-0.00025	0.0017	-0.15	0.88
Low English proficiency × Number of English papers published	-0.0019	0.0032	-0.60	0.55
Moderate English proficiency × Number of English papers published	-0.0093	0.0029	-3.25	0.0012
Lower-middle income	-0.38	0.061	-6.23	4.81×10^{-10}
Variables removed based on the likelihood ratio test	**χ^2**	**P**		
Income level × Number of English papers published	0.062	0.80		

Table S3. Results of a generalised linear model (with a negative binomial distribution) of factors explaining variations in the number of minutes it would take to read and understand the same paper in full, but in their first language. The reference category for English proficiency and Income level was English native and High income, respectively. The number of English papers published was not significant in the likelihood ratio test, but was retained in the final model for a comparison with the result shown in Table S2.

Variables in the final model	**Coefficients**	**Standard errors**	**z**	**p**
Intercept	3.79	0.077		
Low English proficiency	-0.21	0.082	-2.52	0.012
Moderate English proficiency	-0.44	0.091	-4.81	1.55×10^{-6}
Number of English papers published	-0.0010	0.0013	-0.79	0.43
Lower-middle income	-0.23	0.062	-3.73	0.00019
Variables removed based on the likelihood ratio test	**χ^2**	**P**		
English proficiency × Number of English papers published	1.52	0.47		
Income level × Number of English papers published	0.030	0.86		

Table S4. Result of a generalised linear model (with a negative binomial distribution) of factors explaining variations in the number of days taken to write the first draft of each participant's latest first-authored paper in English. The reference category for English proficiency and Income level was English native and High income, respectively.

Variables in the final model	**Coefficients**	**Standard errors**	**z**	**p**
Intercept	3.29	0.085		
Low English proficiency	0.27	0.10	2.72	0.0066
Moderate English proficiency	0.41	0.11	3.85	0.00012
Number of English papers published	0.00016	0.0019	0.087	0.93
Low English proficiency × Number of English papers published	-0.0098	0.0036	-2.72	0.0066
Moderate English proficiency × Number of English papers published	-0.0080	0.0032	-2.50	0.012
Variables removed based on the likelihood ratio test	**χ^2**	**P**		
Income level	1.52	0.22		

Income level × Number of English papers published	0.28	0.60

781

782 Table S5. Result of a generalised linear model (with a negative binomial distribution) of factors
783 explaining variations in the number of days it would take to write the first draft of each participant's
784 latest first-authored paper in their first language. The reference category for English proficiency and
785 Income level was English native and High income, respectively.

Variables in the final model	**Coefficients**	**Standard errors**	**z**	**p**
Intercept	3.25	0.089		
Low English proficiency	-0.47	0.10	-4.57	4.84×10^{-6}
Moderate English proficiency	-0.47	0.11	-4.12	3.86×10^{-5}
Number of English papers published	0.00034	0.0019	0.18	0.86
Low English proficiency × Number of English papers published	-0.011	0.0039	-2.93	0.0034
Moderate English proficiency × Number of English papers published	-0.00063	0.0033	-0.19	0.85
Lower-middle income	0.16	0.070	2.30	0.021
Variables removed based on the likelihood ratio test	**χ^2**	**P**		
Income level × Number of English papers published	0.55	0.46		

786

787 Table S6. Result of a generalised linear model (with a binomial distribution) of factors explaining
788 variations in the percentage of papers where English writing was checked either by someone as a
789 favour or by a paid service. The reference category for English proficiency and Income level was
790 English native and High income, respectively.

Variables in the final model	**Coefficients**	**Standard errors**	**z**	**p**
Intercept	0.18	0.19		
Low English proficiency	1.82	0.28	6.48	9.03×10^{-11}
Moderate English proficiency	2.60	0.31	8.38	$< 0.1 \times 10^{-15}$
Number of English papers published	-0.0084	0.0054	-1.54	0.12
Low English proficiency × Number of English papers published	0.052	0.023	2.25	0.024
Moderate English proficiency × Number of English papers published	-0.0071	0.0084	-0.84	0.40
Lower-middle income	-0.66	0.21	-3.12	0.0018

Variables removed based on the likelihood ratio test	χ^2	P
Income level × Number of English papers published	0.16	0.69

Table S7. Result of a generalised linear model (with a binomial distribution) of factors explaining variations in the percentage of papers where English writing was checked by someone as a favour. The reference category for English proficiency and Income level was English native and High income, respectively.

Variables in the final model	Coefficients	Standard errors	z	p
Intercept	0.45	0.031		
Low English proficiency	-0.70	0.033	-21.51	$< 0.1 \times 10^{-15}$
Moderate English proficiency	0.93	0.035	26.71	$< 0.1 \times 10^{-15}$
Number of English papers published	-0.019	0.0015	-12.61	$< 0.1 \times 10^{-15}$
Low English proficiency × Number of English papers published	-0.0034	0.0018	-1.94	0.052
Moderate English proficiency × Number of English papers published	0.0081	0.0016	4.99	5.93×10^{-7}
Lower-middle income	0.049	0.020	2.41	0.016
Income level × Number of English papers published	-0.0079	0.0014	-5.78	7.44×10^{-9}

Table S8. Result of a generalised linear model (with a binomial distribution) of factors explaining variations in the percentage of papers where English writing was checked by a paid service. The reference category for English proficiency and Income level was English native and High income, respectively.

Variables in the final model	Coefficients	Standard errors	z	p
Intercept	-1.82	0.052		
Low English proficiency	2.67	0.054	49.29	$< 0.1 \times 10^{-15}$
Moderate English proficiency	1.76	0.056	31.29	$< 0.1 \times 10^{-15}$
Number of English papers published	-0.0011	0.0018	-0.61	0.54
Low English proficiency × Number of English papers published	-6.19×10^{-6}	0.0020	-0.0030	> 0.99
Moderate English proficiency × Number of English papers published	-0.0034	0.0020	-1.72	0.085
Lower-middle income	-2.21	0.024	-90.95	$< 0.1 \times 10^{-15}$

Income level × Number of English papers published	0.0046	0.0018	2.51	0.012

Table S9. Result of a generalised linear model (with a binomial distribution) of factors explaining the experience of having a first-authored English-language paper rejected due to English writing. The reference category for English proficiency and Income level was English native and High income, respectively.

Variables in the final model	**Coefficients**	**Standard errors**	**z**	**p**
Intercept	-1.78	0.25		
Low English proficiency	1.18	0.28	4.25	2.18×10^{-5}
Moderate English proficiency	1.30	0.29	4.53	5.88×10^{-6}
Number of English papers published	0.0061	0.0043	1.43	0.15
Low English proficiency × Number of English papers published	0.019	0.0094	2.00	0.046
Moderate English proficiency × Number of English papers published	-0.0053	0.0070	-0.76	0.45
Variables removed based on the likelihood ratio test	**χ^2**	**P**		
Income level	0.013	0.91		
Income level × Number of English papers published	2.00	0.16		

Table S10. Result of a cumulative link model of factors explaining the frequency of being requested to improve English writing in the revision of first-authored English-language papers. The reference category for English proficiency and Income level was English native and High income, respectively.

Variables in the final model	**Coefficients**	**Standard errors**	**z**	**p**
Low English proficiency	2.36	0.20	11.87	$< 0.1 \times 10^{-15}$
Moderate English proficiency	2.08	0.21	9.97	$< 0.1 \times 10^{-15}$
Variables removed based on the likelihood ratio test	**χ^2**	**P**		
Number of English papers published	0.11	0.74		
Income level	2.31	0.13		
English proficiency × Number of English papers published	0.32	0.85		
Income level × Number of English papers published	0.68	0.41		

Table S11. Result of a generalised linear model (with a binomial distribution) of factors explaining the experience of providing a non-English-language abstract of English-language papers. The reference category for English proficiency and Income level was English native and High income, respectively.

Variables in the final model	**Coefficients**	**Standard errors**	**z**	**p**
Intercept	-1.33	0.22		
Low English proficiency	0.48	0.23	2.11	0.035
Moderate English proficiency	1.71	0.25	6.87	6.33×10^{-12}
Number of English papers published	0.014	0.0039	3.62	0.00030
Lower-middle income	-0.61	0.16	-3.74	0.00019
Variables removed based on the likelihood ratio test	**χ^2**	**P**		
English proficiency × Number of English papers published	4.07	0.13		
Income level × Number of English papers published	0.40	0.53		

Table S12. Result of a generalised linear model (with a binomial distribution) of factors explaining the experience of disseminating English-language papers in other language(s) in addition to English. The reference category for English proficiency and Income level was English native and High income, respectively.

Variables in the final model	**Coefficients**	**Standard errors**	**z**	**p**
Intercept	-0.72	0.19		
Low English proficiency	0.33	0.22	1.48	0.14
Moderate English proficiency	0.67	0.24	2.78	0.0055
Number of English papers published	-0.0014	0.0045	-0.30	0.76
Low English proficiency × Number of English papers published	0.011	0.0082	1.33	0.18
Moderate English proficiency × Number of English papers published	0.027	0.010	2.60	0.0092
Variables removed based on the likelihood ratio test	**χ^2**	**P**		
Income level	1.87	0.17		
Income level × Number of English papers published	1.24	0.26		

Table S13. Result of a cumulative link model of factors explaining the frequency of not attending an English-language conference due to a lack of confidence in English communication. The reference category for English proficiency and Income level was Low English proficiency and High income, respectively.

Variables in the final model	**Coefficients**	**Standard errors**	**z**	**p**
Number of English papers published	-0.014	0.0049	-2.82	0.0047
Lower-middle income	-0.99	0.16	-6.36	2.00×10^{-10}
Variables removed based on the likelihood ratio test	**χ^2**	**P**		
English proficiency	0.072	0.79		
English proficiency × Number of English papers published	1.27	0.26		
Income level × Number of English papers published	1.27	0.26		

Table S14. Result of a cumulative link model of factors explaining the frequency of avoiding oral presentations at an English-language conference due to a lack of confidence in English communication. The reference category for English proficiency and Income level was Low English proficiency and High income, respectively.

Variables in the final model	**Coefficients**	**Standard errors**	**z**	**p**
Moderate English proficiency	0.32	0.16	2.00	0.046
Number of English papers published	-0.020	0.0050	-3.99	6.67×10^{-5}
Lower-middle income	-1.37	0.17	-8.00	1.22×10^{-15}
Variables removed based on the likelihood ratio test	**χ^2**	**P**		
English proficiency × Number of English papers published	0.049	0.83		
Income level × Number of English papers published	0.52	0.47		

Table S15. Results of a generalised linear model (with a negative binomial distribution) of factors explaining variations in the number of hours taken to prepare and practice an oral presentation in English. The reference category for English proficiency and Income level was English native and High income, respectively. The number of English papers published was not significant in the likelihood ratio test, but was retained in the final model for a comparison with other results.

Variables in the final model	Coefficients	Standard errors	z	p
Intercept	2.85	0.10		
Low English proficiency	0.32	0.11	2.97	0.0030
Moderate English proficiency	0.66	0.12	5.56	2.67×10^{-8}
Number of English papers published	0.00050	0.0016	0.31	0.76
Lower-middle income	-0.27	0.082	-3.26	0.0011
Variables removed based on the likelihood ratio test	**χ^2**	**P**		
English proficiency × Number of English papers published	1.78	0.41		
Income level × Number of English papers published	0.025	0.87		

836

837 Table S16. Results of a generalised linear model (with a negative binomial distribution) of factors
838 explaining variations in the number of hours that would be taken to prepare and practice the same oral
839 presentation in the first language. The reference category for English proficiency and Income level
840 was English native and High income, respectively. The number of English papers published was not
841 significant in the likelihood ratio test, but was retained in the final model for a comparison with other
842 results.

Variables in the final model	Coefficients	Standard errors	z	P
Intercept	2.88	0.11		
Low English proficiency	-0.41	0.12	-3.58	0.00034
Moderate English proficiency	0.046	0.12	0.37	0.71
Number of English papers published	0.00031	0.0017	0.18	0.86
Lower-middle income	-0.34	0.087	-3.87	0.00011
Variables removed based on the likelihood ratio test	**χ^2**	**P**		
English proficiency × Number of English papers published	4.54	0.10		
Income level × Number of English papers published	2.80	0.095		

843

844 Table S17. Result of a cumulative link model of factors explaining the frequency of not being able to
845 explain research confidently during a presentation due to English barriers. The reference category for
846 English proficiency and Income level was Low English proficiency and High income, respectively.

Variables in the final model	Coefficients	Standard errors	z	p

Moderate English proficiency	-0.52	0.15	-3.41	0.00065
Number of English papers published	-0.017	0.0039	-4.29	1.79×10^{-5}
Lower-middle income	-0.98	0.15	-6.37	1.94×10^{-10}

Variables removed based on the likelihood ratio test	χ^2	**P**
English proficiency × Number of English papers published	0.38	0.54
Income level × Number of English papers published	0.82	0.36

847

848

849 Table S18. Examples of potential solutions to reducing disadvantages for non-native English speakers
850 in each type of scientific activities. Also see (*23, 35, 36*) for other potential solutions.

Scientific activity	Potential solutions
Paper reading	Institutions provide training opportunities for academic English reading.
	Supervisors/collaborators acknowledge that non-native English speakers require more time to read articles in English.
	Universities incorporate materials that are available in students' first languages, if available, into education.
	Journals support and encourage publishing the translation of English-language papers, for example through granting a copyright release.
Paper writing	Institutions provide training opportunities for academic English writing.
	Funders/institutions establish grant schemes to cover professional English editing/translation services, especially for those from less economically developed regions and at early career levels.
Paper publication	Journals develop guidelines for editors and reviewers to ensure that their decisions are purely based on the quality of science, not linguistic fluency.
	Journals establish a "buddy" system where non-native English speakers can receive English editing support from native English speakers.
Paper dissemination	Institutions financially support research dissemination in multiple languages
	Funders/institutions value efforts to disseminate research in multiple languages as an important component of research outcomes.
Participation in conferences	Conferences establish a "buddy" system where non-native English speakers can receive support from native English speakers for presentation preparation.
	Conferences allow non-native English speakers to present their research in the first languages while providing English subtitles.

851

Supplementary Figures

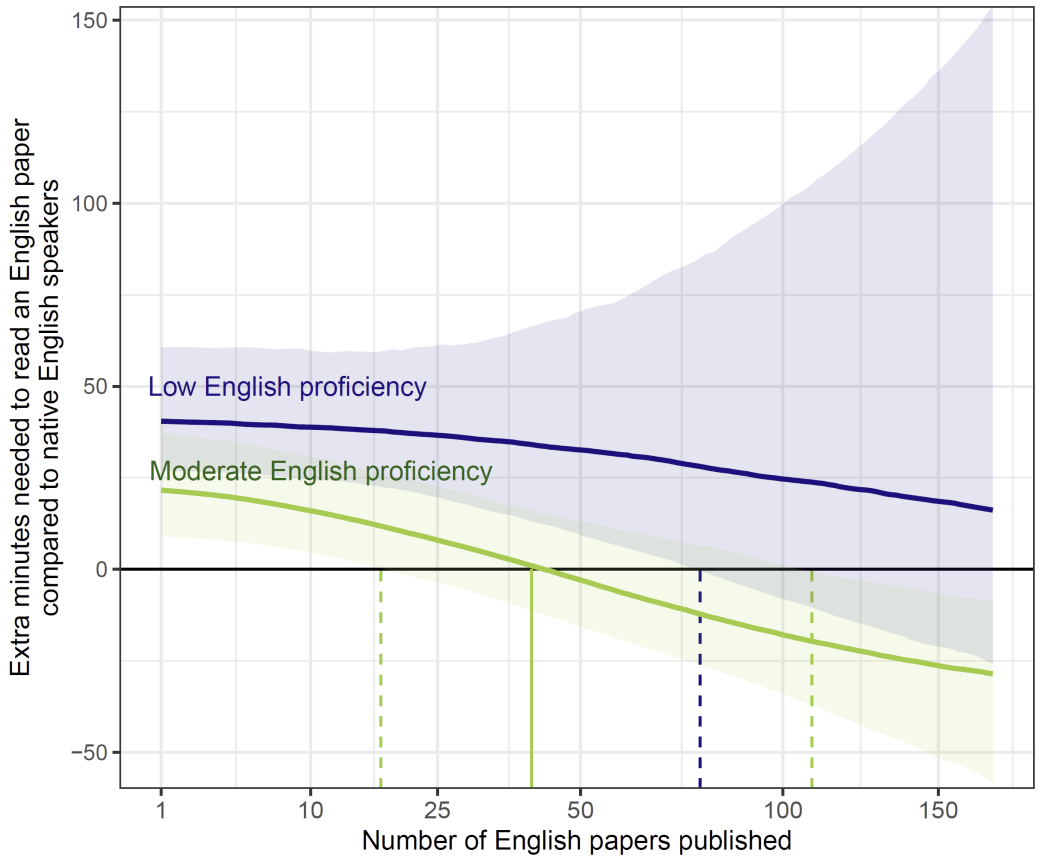


Fig. S1. The number of extra minutes (and its 95% confidence intervals as shaded areas) estimated to take researchers of moderate (green) and low (navy) English proficiency nationalities to read and understand the entire content of the last English-language original article they read in their field, compared to native English speakers, in relation to the number of English-language papers published. The estimations are based on the results of the regression shown in Table S2. The solid vertical lines (and 95% confidence intervals as broken vertical lines) indicate the number of English-language papers published, as a measure of career level, where non-native English speakers do not take longer to read an English-language paper than native English speakers. Non-native English speakers who have published only one English-language paper were estimated to require, on average, 40.92 (low English proficiency nationalities) and 20.77 (moderate English proficiency nationalities) more minutes to read an English-language article, compared to their native-English-speaking counterparts. If they were to read 200 articles per year (average number of article readings per year for US faculty (*37*)), this equates to 19.5 (low English proficiency nationalities) and 9.9 (moderate English proficiency nationalities) more working days per year, assuming a seven-hour working day.

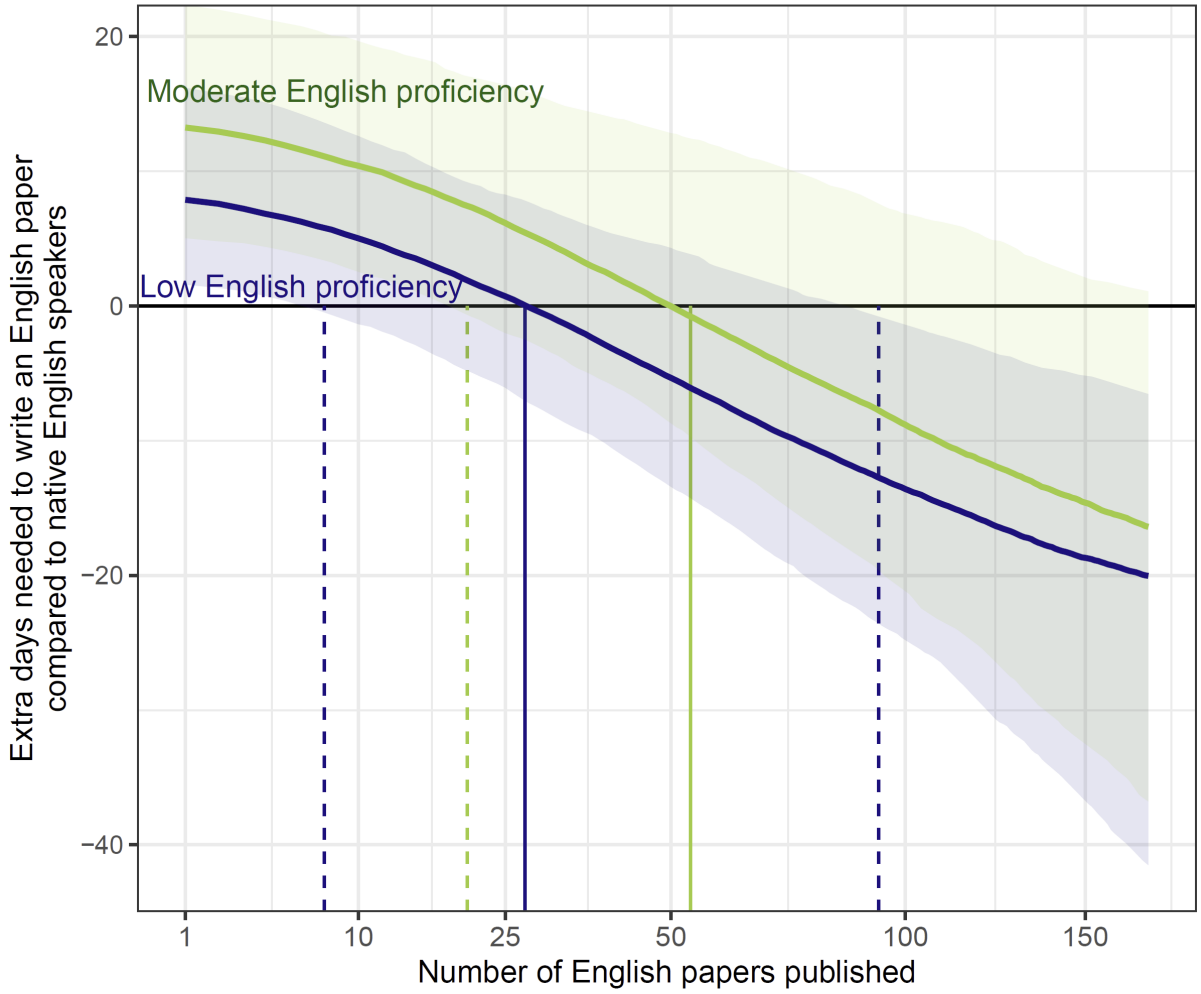
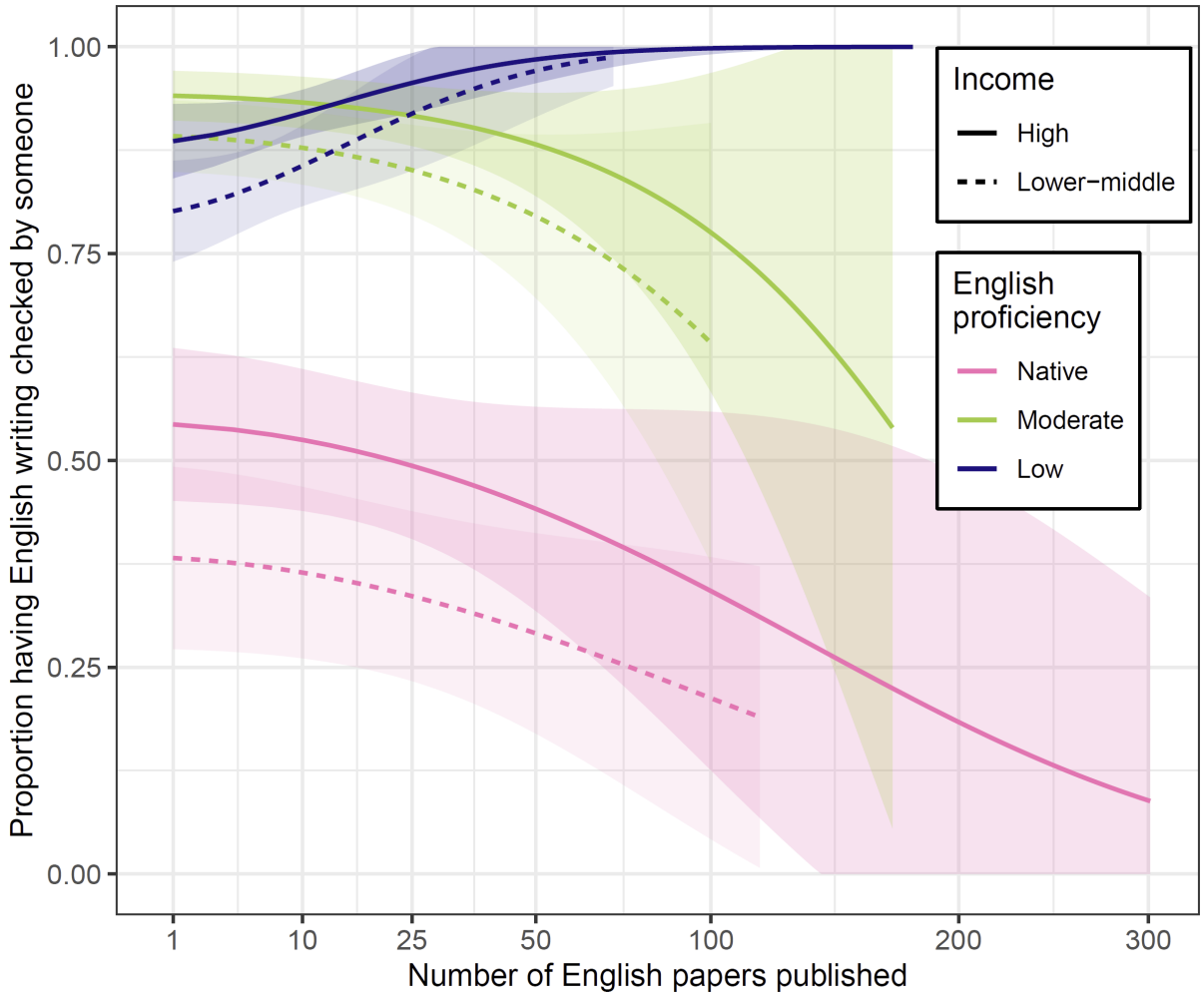
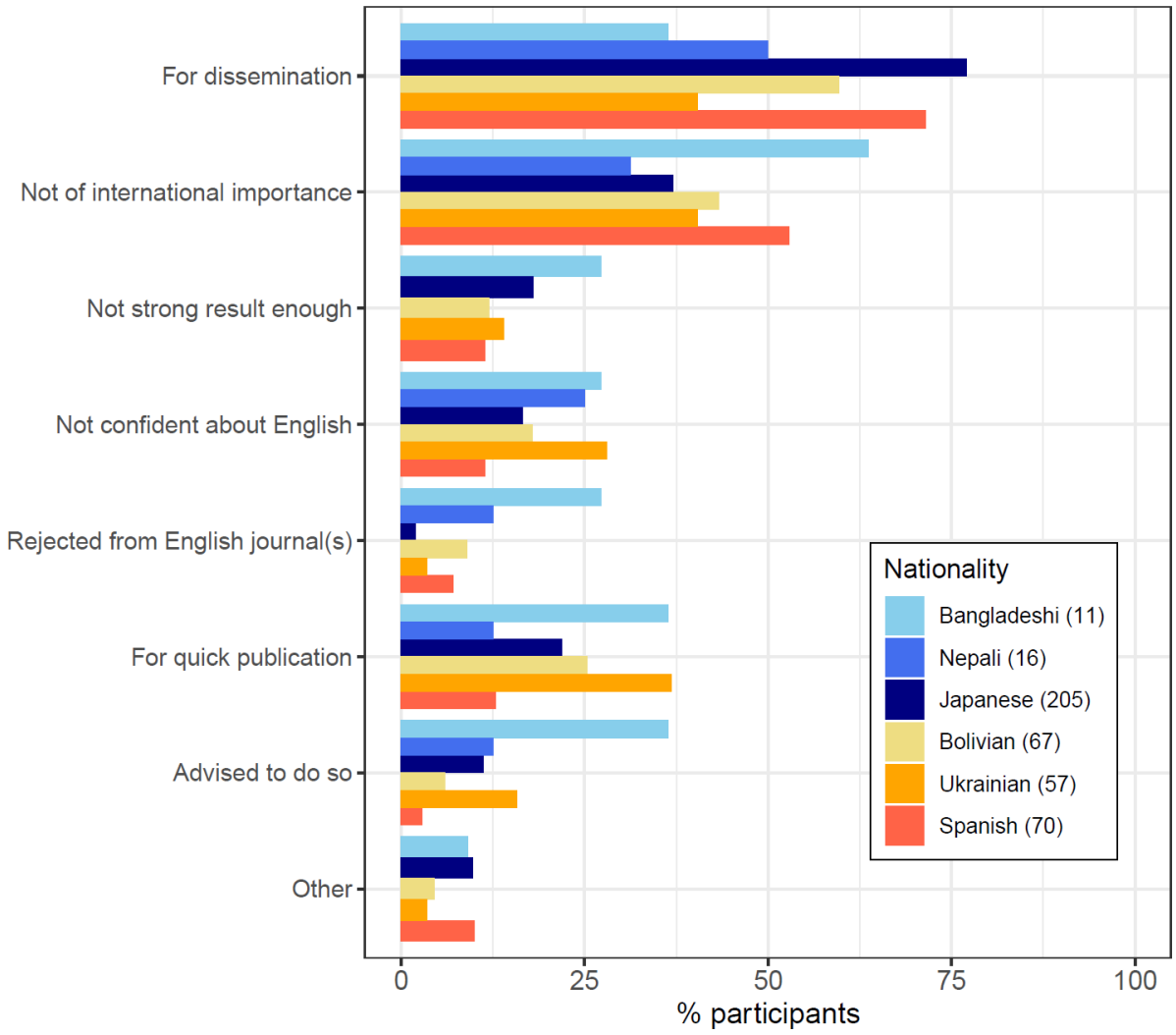


Fig. S2. The number of extra days (and its 95% confidence intervals as shaded areas) estimated to take researchers of moderate (green) and low (navy) English proficiency nationalities to write the first draft of their latest first-authored paper in English, compared to native English speakers, in relation to the number of English-language papers published. The estimations are based on the results of the regression shown in Table S4. The solid vertical lines (and 95% confidence intervals as broken vertical lines) indicate the number of English-language papers published, as a measure of career level, where non-native English speakers do not take longer to write an English-language paper than native English speakers.



877

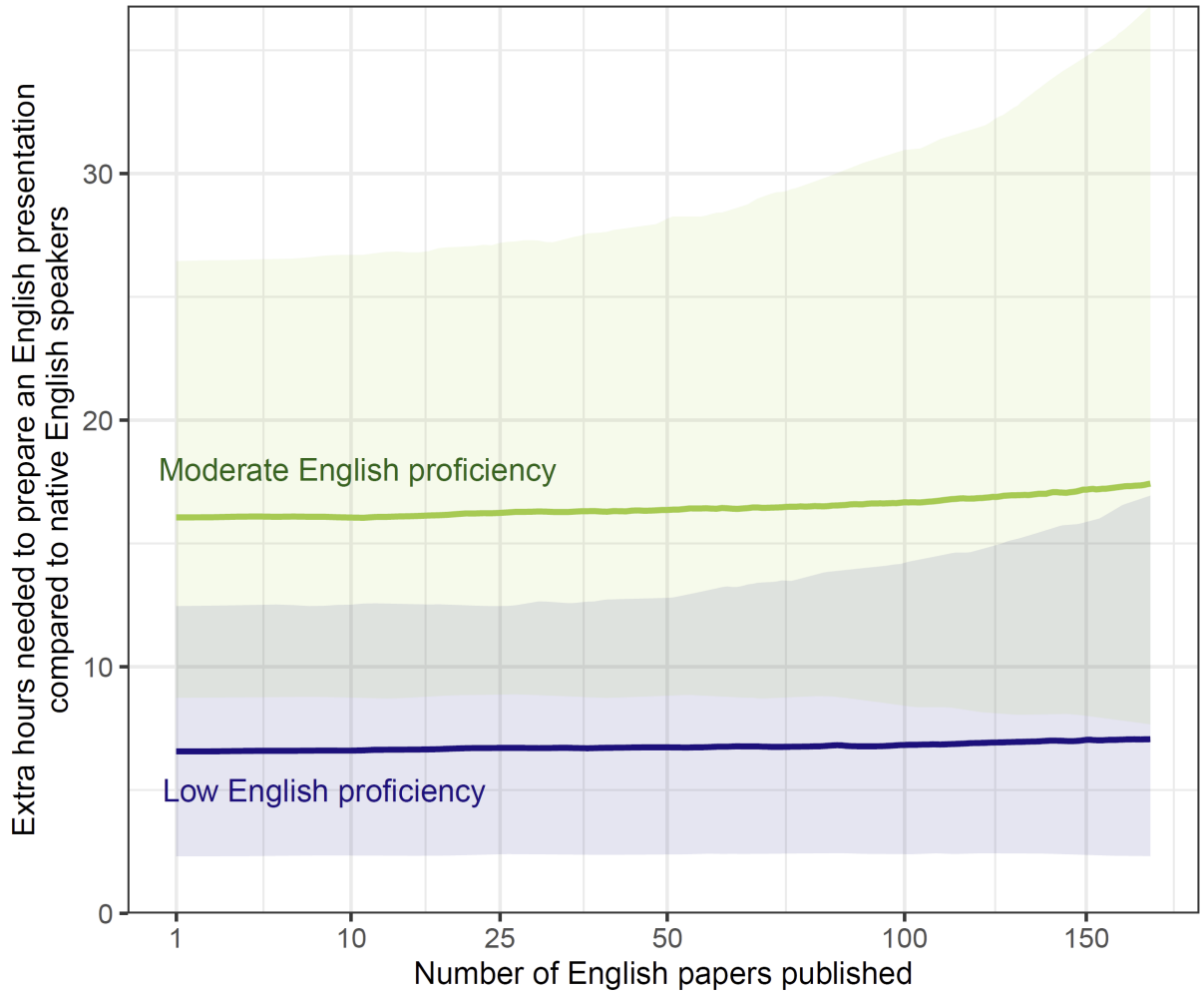
878 Fig. S3. The proportion of researchers who have their English writing checked either by someone as a
879 favour or by a professional service. The regression lines (with 95% confidence intervals as shaded
880 areas) represent the estimated relationship with the number of English-language papers published,
881 based on the results shown in Table S6.



882

883 Fig. S4. Reasons for non-native English speakers to submit their papers to non-English-language
884 journals by nationality. Participants were allowed to choose multiple reasons, and the x-axis indicates
885 the percentage of participants who selected each reason.

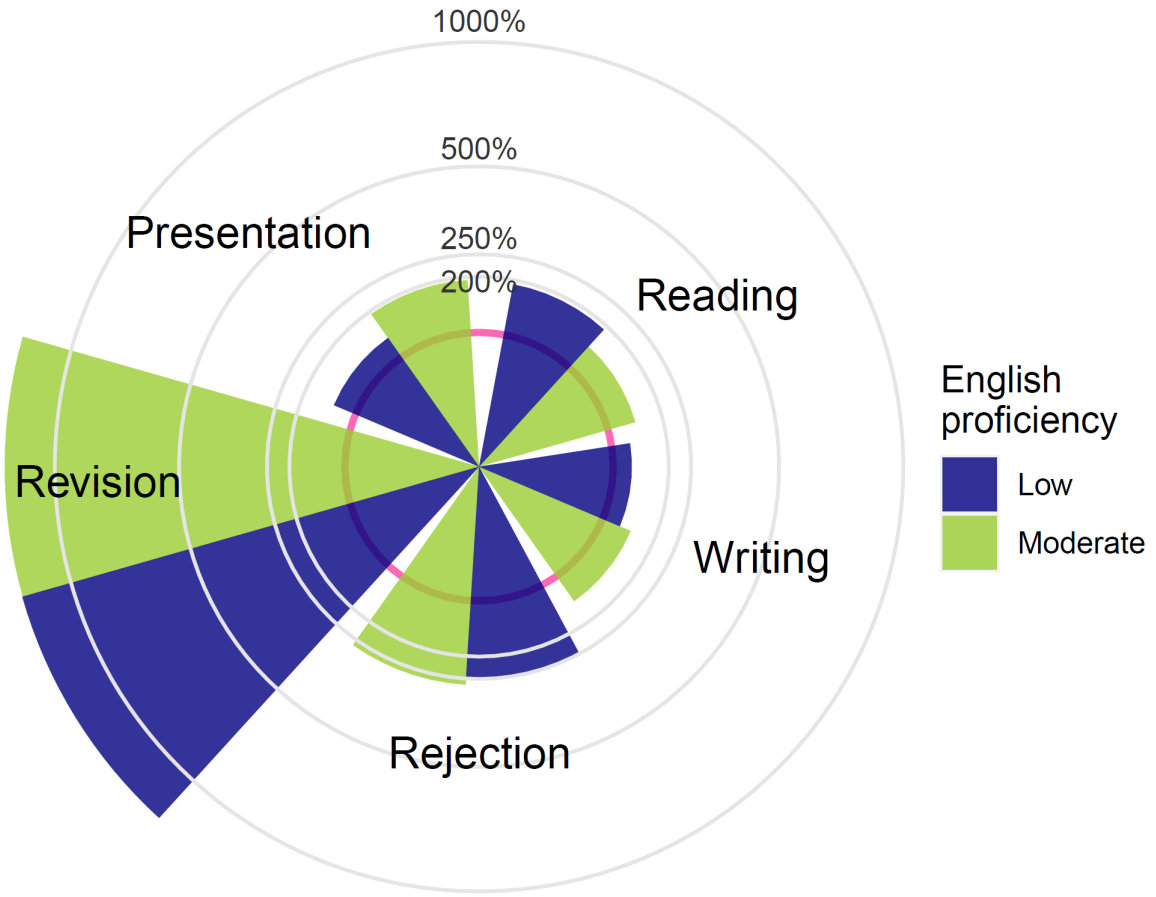
886



887

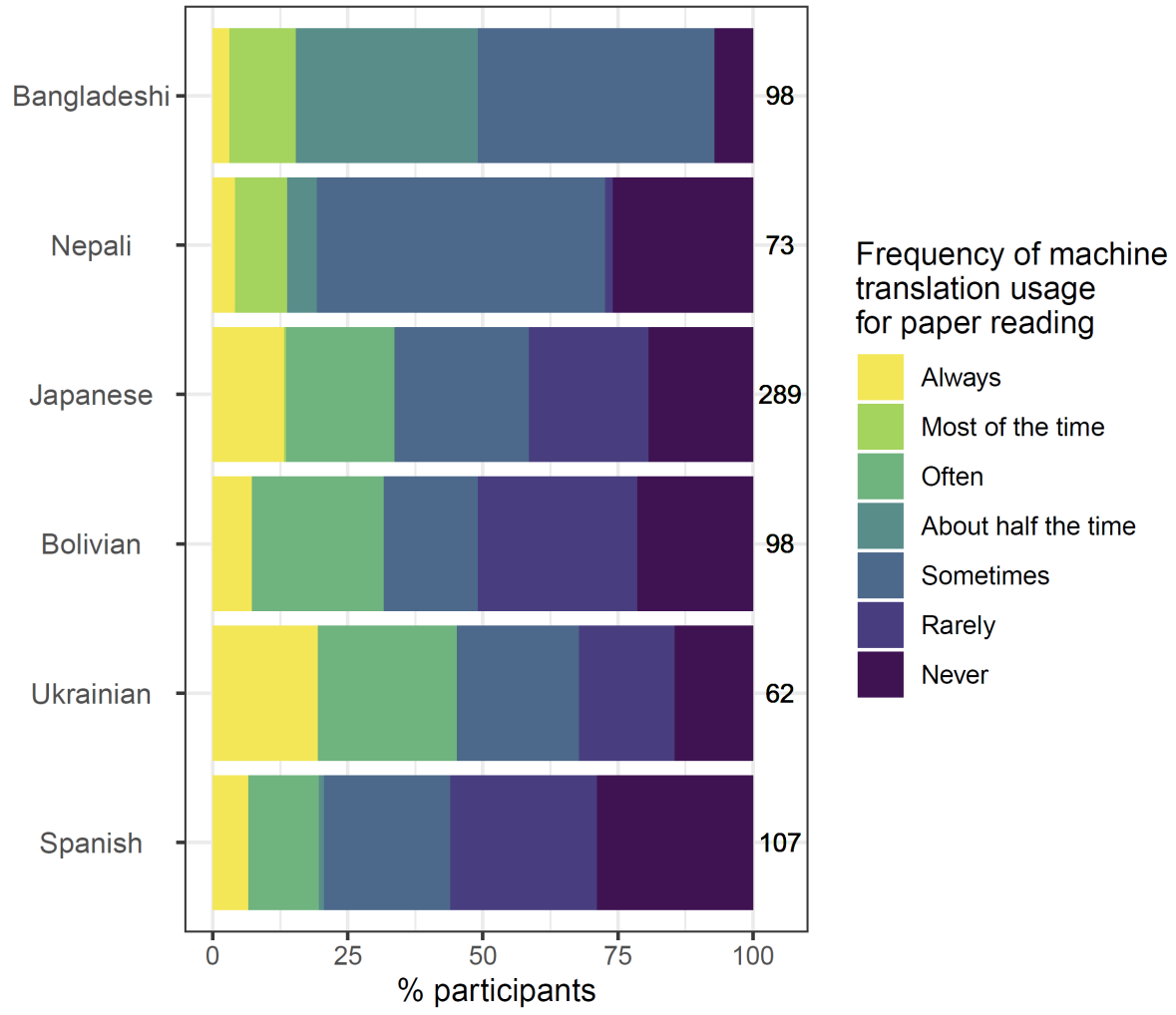
888 Fig. S5. The number of extra hours (and its 95% confidence intervals as shaded areas) estimated to
889 take researchers of moderate (green) and low (navy) English proficiency nationalities to prepare and
890 practice an oral presentation in English, compared to native English speakers, in relation to the number
891 of English-language papers published. The estimations are based on the results of the regression
892 shown in Table S15.

893



894

895 Fig. S6. Estimated disadvantages for non-native English speakers when conducting different scientific
896 activities. Bars indicate the relative (in percentages) length of time taken to read an English-language
897 paper (Reading), to write a paper in English (Writing), and to prepare an oral presentation in English
898 (Presentation), and the relative frequency of an English-language paper being rejected (Rejection) or
899 requested to revise (Revision) due to English writing, for non-native English speakers of low (blue)
900 and moderate (green) English proficiency nationalities. The values are for non-native English speakers
901 who have published only one English-language paper, compared to the values for native English
902 speakers (the circle shown in pink).

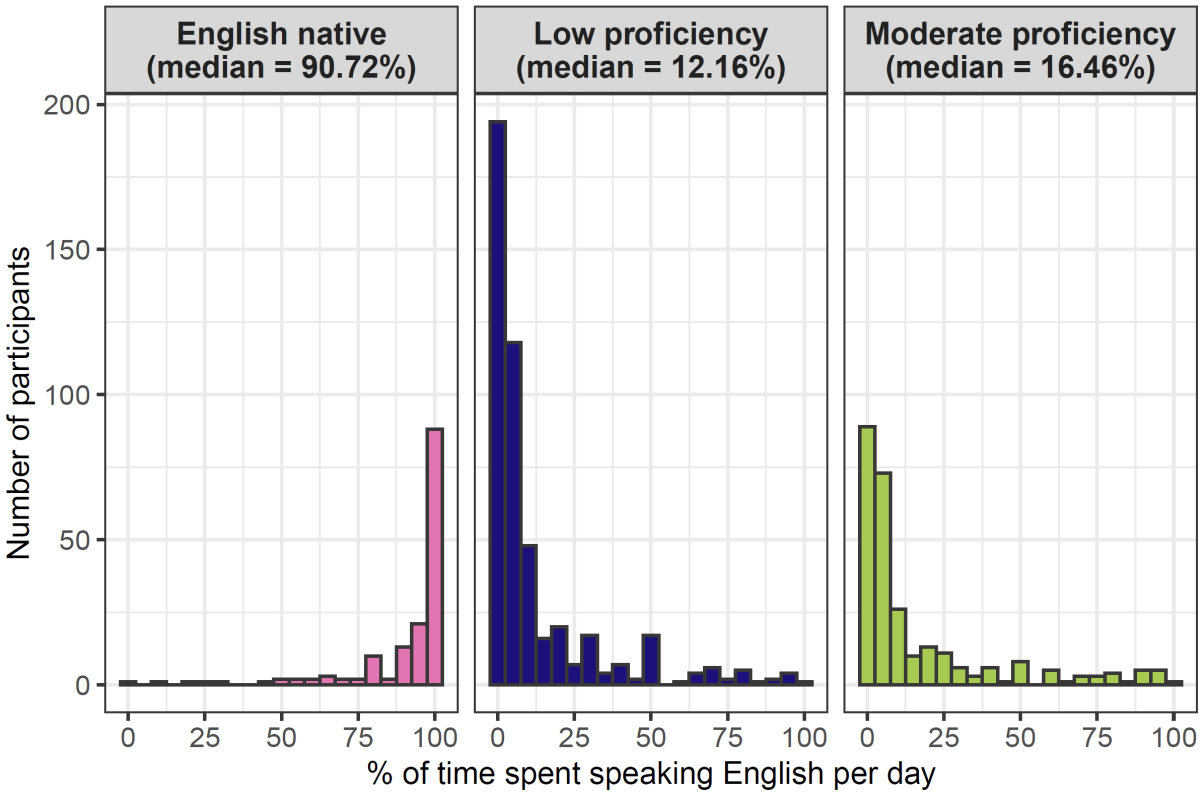


903

904 Fig. S7. The frequency of machine translation usage when reading English-language papers by

905 nationality.

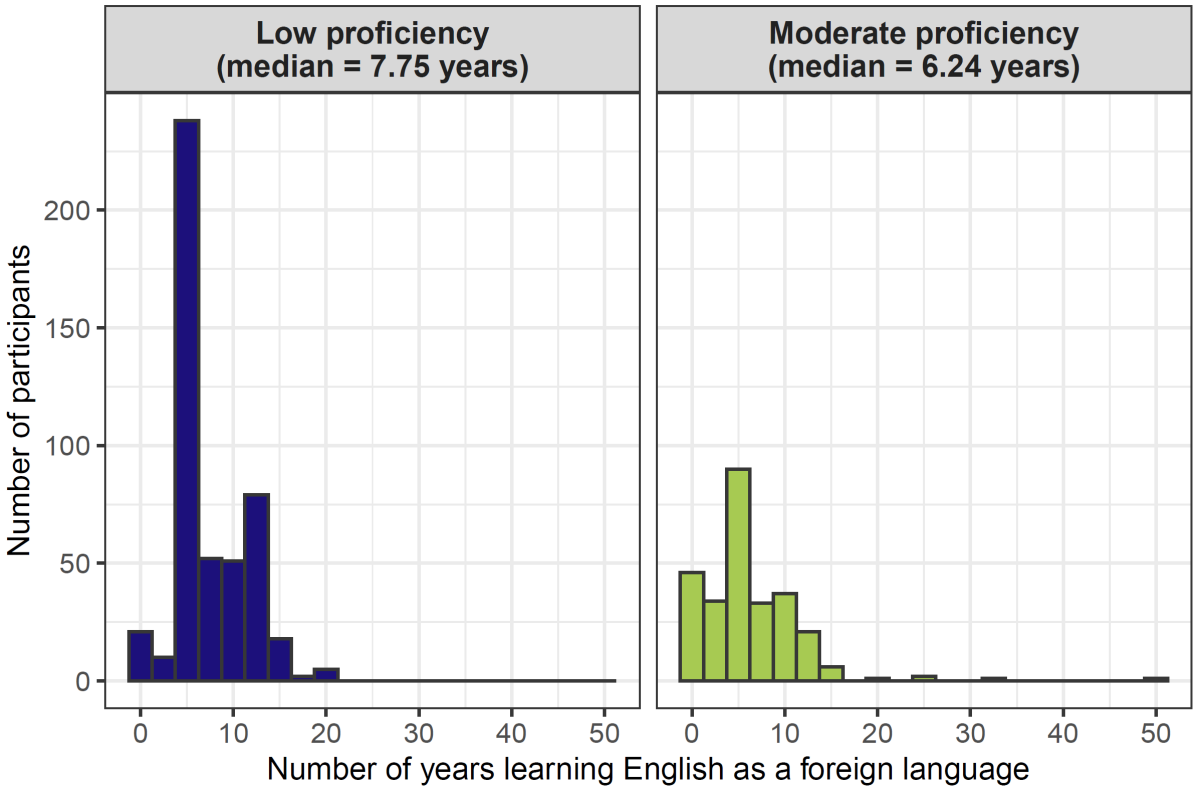
906



907

908 Fig. S8. The percentage of time spent speaking English, per day, in daily life. Researchers of moderate
909 English proficiency nationalities speak English in daily life significantly more than those with low
910 English proficiency (generalised linear model with a binomial distribution: Coefficient = 0.35,
911 Standard Error = 0.022, $z = 16.40$, $p < 2.0 \times 10^{-16}$).

912



913

914 Fig. S9. The number of years learning English as a foreign language. Researchers of moderate English
915 proficiency nationalities have been spending a significantly fewer number of years learning English
916 than those of low English proficiency nationalities (generalised linear model with a negative binomial
917 distribution: Coefficient = -0.22, Standard Error = 0.044, z = -4.96, $p = 7.23 \times 10^{-7}$).

918

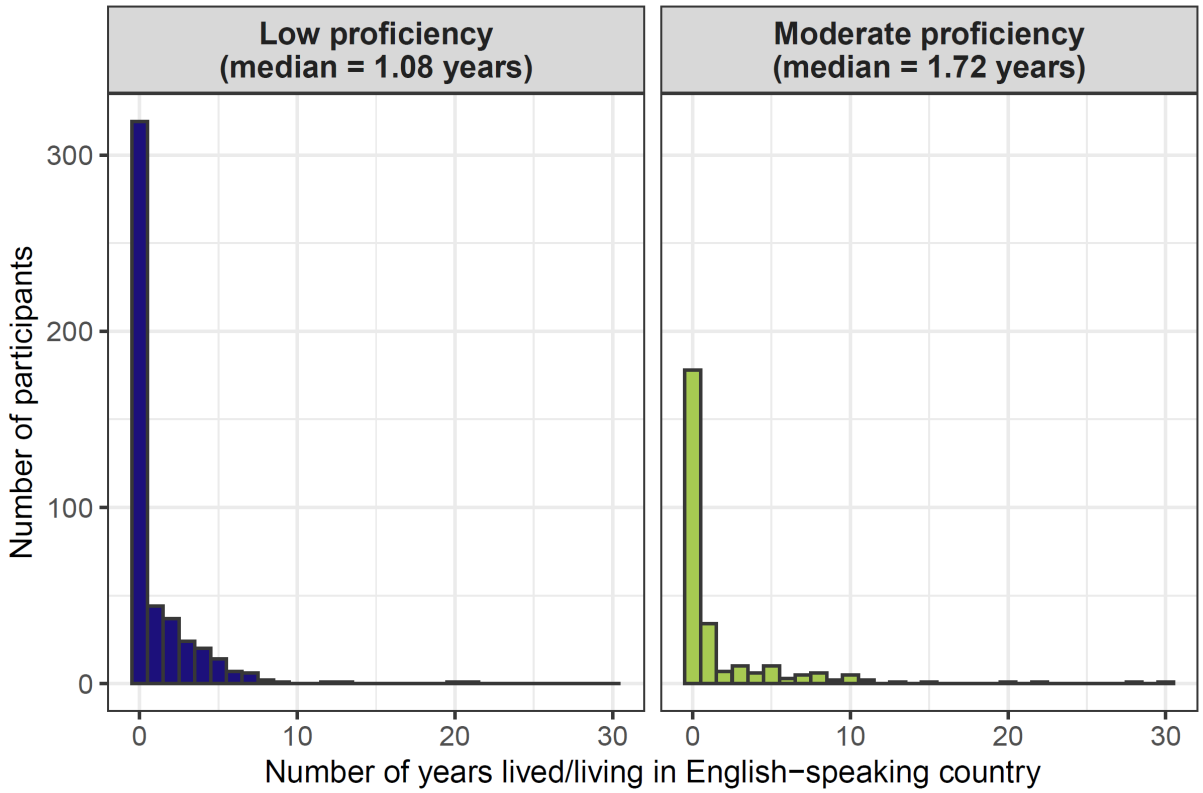


Fig. S10. The number of years lived/living in countries where English is the first language. Researchers of moderate English proficiency nationalities have lived in a country where English is the first language significantly longer than those of low English proficiency nationalities (generalised linear model with a negative binomial distribution: Coefficient = 0.47, Standard Error = 0.17, z = 2.69, p = 0.0072).

Supplementary Text S1. Questionnaire survey on consequences of language barriers for non-native English speakers for developing career in science.

Survey on the cost of being a non-native English speaker in science

Potential participants are kindly asked to read the participant information sheet below before deciding whether or not to participate in this survey.

Participant information sheet

Background

Being a non-native-English speaker could pose multiple disadvantages when pursuing a career in scientific research, where English is widely recognised as a common language for communication. However, few attempts have been made to quantify the actual cost of being a non-native English speaker in scientific research globally. This has impeded our understanding of language barriers in scientific career developments, potentially leading to the lack of concerted efforts to tackle this issue.

Aim

This survey aims to understand the cost of being a non-native-English speaker in sciences and is targeted at anyone with an eligible nationality (i.e., see list of eligible nationalities below) at any career level and of any profession who has published at least one first-authored peer-reviewed English-language paper on ecology, evolutionary biology, conservation biology or related disciplines. The survey will collect information on, for example, the amount of time needed to write a paper or prepare a presentation in English, which will be compared (i) between non-native and native English speakers, and (ii) between countries with different income levels.

Eligible nationalities are Bangla, Bolivian, Japanese, Nepali, Nigerian, Ukrainian, Spanish, United Kingdom (i.e., British, English, Northern Irish, Scottish or Welsh).

What is involved?

Participation in this study is entirely online and will take approximately 20 minutes and the survey can

be undertaken at a time and place that is convenient to you.

Participation and withdrawal

Participation in this study is completely voluntary and you are free to withdraw from this study at any time. If you wish to withdraw, simply stop by closing your internet browser and no data will be saved. Feel free to ask any questions about the research (contact the project or relevant country coordinator).

Risks

Participation in this study should involve no physical or mental discomfort and no risks beyond those of everyday living. If, however, you should find any question to be offensive, you are free to omit answering or participating in the specific question.

Confidentiality and security of data

Your responses to the survey are anonymous; no identifying information will be collected. All other data will be stored on password-protected computers and only members of the research team will have access to the data. Because all data is non-identifiable, it cannot be linked to individual participants and data will only be presented as summaries of overall responses. The data you provide will only be used for the specific research purposes of this study.

Benefits of your participation in the study

The data from the survey will shed light on the consequences of language barriers to scientific career developments of non-native English speakers, which will then be used for raising awareness about the issue among scientific communities and making concerted efforts to reduce language barriers to non-native-English speaking scientists.

Ethics clearance and contacts

This study has been cleared in accordance with the ethical review guidelines and processes of the University of Queensland. These guidelines are endorsed by the University's Human Ethics Committee and registered with the Australian Health Ethics Committee as complying with the National Statement. You are free to discuss your participation in this study with project staff. If you would like to speak to an officer of the University not involved in the study, you may contact the

University of Queensland Ethics Officer on +61 3365 3924.

Study results and further information

The results will be published online in scientific journals and shared at conferences. You will not be identifiable in any outputs as your data will only be included in an anonymous and aggregated form. If you would like to learn the outcome of the study, please feel free to email the project staff (see below) and we can organise to send you a summary of the study once it is complete. You can also obtain general information on the project at: https://translatesciences.com/.

Thank you for your participation in this study.

Dr Tatsuya Amano, ARC Future Fellow
School of Biological Sciences, The University of Queensland, Brisbane, Qld 4072, Australia. Email: t.amano@uq.edu.au

Violeta Berdejo-Espinola, Senior Research Technician
School of Biological Sciences, The University of Queensland, Brisbane, Qld 4072, Australia. Email: v.berdejoespinola@uq.edu.au

[Country coordinator details]

Consent form

By checking the two boxes below, you confirm that you have read and understood the above and give your consent for your response to be used in this study:

☐ I have read the information provided about the research project and understand the nature of my involvement. I understand any information I provide is completely confidential. I agree to take part and understand I can withdraw at any time.

☐ I am aged 18 or older.

Language and nationality

1.1 What is your first language? For the purpose of this survey first language(s) are defined as "*the*

language(s) you learnt to speak at home as a child".

- ○ Bangla
- ○ English
- ○ Japanese
- ○ Nepali
- ○ Spanish
- ○ Ukrainian
- ○ Other

Please describe. _____

1.2 Please state your nationality.

- ○ Bangladesh
- ○ Bolivia
- ○ Japan
- ○ Nigeria
- ○ Nepal
- ○ Ukraine
- ○ Spain
- ○ United Kingdom (i.e., British, English, Northern Irish, Scottish or Welsh)
- ○ Other

Basic information

2.1 How old are you?

▼ 18 ... >80

2.2 Please state your gender identity below.

- ○ Male
- ○ Female
- ○ Prefer to self-describe
- ○ Prefer not to say

Please describe. _____

2.3 Which of the following disciplines best describes your research area (choose only one)?

- ○ Conservation Biology
- ○ Ecology
- ○ Evolutionary Biology
- ○ Other biological sciences

Please describe. _____

- ○ Sciences other than biological sciences

Please describe. _____

- ○ Other

Please describe. _____

2.4 Please state the number of years you have been working in research (including the period of your masters and doctoral degrees, if applicable, but not bachelor's degree).

▼ 1 ... 80

2.5 What is the percentage of time in a day that you speak in English in your daily life?

▼ 0% ... 100%

2.6 How many years have you learnt English as a foreign language (before starting undergraduate

education)?

▼ 0 ... 80

2.7 How many years have you lived in countries or environments where English is the first language?

▼ 0 ... >50

Paper writing in English

3.1 How many peer-reviewed papers (of any categories, such as original research, reviews, perspectives, etc) have you published as the **first author** in **English**?

▼ 0 ... 300

3.2 How many peer-reviewed papers have you published as the first author in any other languages (i.e., non-English languages)?

▼ 0 ... 300

3.3 How many days did it take for you to finish writing the first full draft of your latest first-authored paper in **English** after obtaining the results of your study (assuming you spend seven hours writing the article each day and excluding time spent for non-writing, such as waiting for coauthors' comments, etc)?

▼ <1 ... 120

3.4 How many days would it take for you to finish writing the same article but in **your first language** after obtaining the results of your study (assuming you spend approximately seven hours writing the article each day and excluding time spent for non-writing, such as waiting for coauthors' comments, etc)?

▼ <1 ... 120

3.5 Have you ever asked someone (including your coauthor(s)) to improve the quality of your English

writing (e.g., for correcting grammar) as a favour or using a professional service?

- ○ Yes
- ○ No

3.6 What is the percentage of your first-authored papers where you have asked someone (including your coauthor(s)) for a favour to improve the quality of your English writing (e.g., for correcting grammar)?

▼ 1 ... 100%

3.7 What is the percentage of your first-authored papers where you or your coauthor(s) have paid for a professional service to improve the quality of your English writing (e.g., for correcting grammar)?

▼ 1 ... 100%

Publications in English

4.1 Have you ever experienced the rejection of your first-authored paper from any English-language journal where at least one of the reasons for the rejection was your English writing?

- ○ Yes
- ○ No

4.2 How often have you been requested to improve your English writing (e.g., requested to use an English editing service, or ask your colleague to do English editing, etc) in the revision of your first-authored paper in any English-language journal?

▼ Always ... Never

4.3 If you have ever submitted your paper(s) to any journal(s) published in a non-English language(s), what was the reason for you to choose the language(s) for publishing your paper(s)? Please select the reasons below (you can select multiple reasons).

- ☐ The topic of the paper is not of international importance (e.g., specific to your country).
- ☐ The result was not strong enough to be published in an English-language journal (e.g., the

result was not statistically significant).

☐ It was rejected from English-language journal(s).

☐ You were not confident enough about your English writing.

☐ You wanted to publish it as soon as possible.

☐ You wanted to disseminate the result to speakers of the language(s), such as local researchers, the general public and/or policymakers in your country.

☐ Your co-author(s) or supervisor(s) advised you to do so.

☐ Other.
Please describe. _____

☐ Not applicable.

4.4 Have you ever provided the non-English-language abstract of your English-language paper(s)?

○ Yes

○ No

4.5 Have you ever conducted outreach activities (e.g., publishing a press release or writing a blog post) in English AND any other language(s) to disseminate your English-language paper(s)?

○ Yes

○ No

Paper reading in English

5.1 How many minutes did it take for you to fully read and understand the last **English-language** original article you read in your field (e.g., ecology)?

▼ 1 ... 180

5.2 How many minutes do you think it would take for you to read and fully understand the same

English-language paper if you could read it in your first language?

▼ 1 ... 180

5.3 How often do you use machine translation (e.g., Google Translate) when reading English-language papers?

▼ Always ... Never

Conferences in English

6.1 Have you attended a conference where English is the primary language?

- ○ Yes
- ○ No

6.2 How often have you decided not to attend an English-language conference (either for presenting your research or just for participating) because you were not confident enough to communicate in English?

▼ Always ... Never

6.3 If you have ever attended an English-language conference, how often have you decided to present your research as a poster presentation, instead of an oral presentation, at an English-language conference because you were not confident enough to do an oral presentation in English?

▼ Always ... Never

6.4 If you have ever given an oral presentation in English, how many hours did it take for you to prepare and practice the last oral presentation in **English**?

▼ <1 ... 100

6.5 How many hours would it take for you to prepare and practice the same presentation but in **your**

first language?

▼ <1 ... 100

6.6 If you have ever presented your research in English, how often have you experienced a situation where you could not explain your research confidently during your presentation (including Q & A sessions) due to language barriers (e.g., because you are not confident about communication in English)?

▼ Always ... Never

Closing section

7.1 Do you have any comments about language barriers for non-native English speakers in academia?

_____

7.2 Please provide any feedback about this survey here.

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Thank you. Please submit your responses by clicking on the right arrow below

Please visit our website to see more of what we do.

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