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Perceived and observed biases within scientific communities: a case study in movement ecology

Allison K. Shaw, Leila Fouda, Stefano Mezzini, Nilanjan Chatterjee, David Wolfson, Briana Abrahms, Christine E Beardsworth, Roxanne Beltran, Sandra A Binning, Kayla M Blincow, et al.

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Title:

2 Perceived and observed biases within scientific communities: a case study in movement ecology

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256 **Abstract**

Who conducts biological research, where, and how the results are disseminated varies among
258 geographies and identities. Identifying and documenting these forms of bias by research
communities is a critical first step towards addressing them. We documented perceived and
260 observed biases in movement ecology. Movement ecology is a rapidly expanding sub-discipline
of biology, which is strongly underpinned by fieldwork and technology use. First, we surveyed
262 attendees of an international conference, and discussed the results at the conference (comparing
uninformed vs informed perceived bias). Although most researchers identified as bias-aware,
264 only a subset of biases were discussed in conversation. Next, by considering author affiliations
from publications in the journal *Movement Ecology*, we found among-country discrepancies
266 between the country of the authors' affiliation and study site location related to national
economics. At the within-country scale, we found that race-gender identities of postgraduate
268 biology researchers in the USA differed from national demographics. We discuss the role of
potential specific causes for the emergence of bias in the sub-discipline, e.g. parachute-science or
270 accessibility to fieldwork. Undertaking data-driven analysis of bias within research sub-
disciplines can help identify specific barriers and first steps towards the inclusion of a greater
272 diversity of participants in the scientific process.

274 **Keywords**

academic conference, diversity, equity, journal authorship, parachute science, representation

276 **Introduction**

278 Biases (systematic distortions with respect to the distribution of a reference population)
universally affect the production and dissemination of scientific research. These biases include
280 the topics prioritised for funding [1,2] and publication [3,4], which papers are cited [5–7], the
language in which results are communicated [8,9], and the identities of authors in the peer-
282 reviewed literature, especially in high-impact international journals [10,11]. Indeed, the
composition of the scientific community itself reflects long-standing biases in terms of gender
284 [12–15], race and ethnicity [16,17], socioeconomic status and family education level [18,19].
Beyond ethical concerns, these biases limit scientific progress and constrain insights and
286 innovations [20]. For example, a lack of researcher gender diversity can limit the research
questions and topics addressed [21]. Cultural biases can also impact interpretation of science
288 [22]. Finally, omission of Indigenous Knowledge can lead to knowledge gaps: traditional
sustainable ways of living [23], or lost animal migratory corridors [24], and perpetuate
290 inequalities that impact science policy decision-making [25]. Within biology, biases also include
the geographic locations of research [7,26] and taxonomic group(s) studied [27–29].

292

There is an urgent need for the scientific community to document how these biases develop,
294 persist, and change, in order to work proactively towards the goal of broadening equitable
participation [30]. Yet, the range of these biases are rarely quantified within specific disciplines.
296 Only studying biases at a broad disciplinary level (e.g., across all of biology) can risk
overlooking important sub-discipline-specific factors which are needed to formulate targeted
298 actions to rectify inequities. Aiming to solve issues at the sub-discipline level can be more

approachable. Often in biology, there are sub-discipline-specific communities that can be
300 succinctly targeted to improve their participation on shorter time scales than an entire
disciplinary field. Case studies within sub-disciplines can also illustrate concrete examples of
302 biases and suggest potential paths forward. Within a sub-discipline, examining bias at different
scales (for example, clarifying if biases manifest within or among countries; [9]) helps shape the
304 scope and nature of potential solutions. Furthermore, determining the extent to which researchers
in a sub-discipline discern biases (perceived bias) and the degree to which biases manifest in the
306 quantifiable activities of that discipline (observed bias) represent critical initial steps in
identifying potential solutions.

308

This paper uses movement ecology as a case study of bias across scales. Movement ecology
310 [29,31,32] is an emerging sub-discipline of biology that is increasingly represented in high-
impact journals [33–35], and is the subject of a recently launched journal (*Movement Ecology*),
312 and multiple international conferences. The recent growth of this sub-discipline emphasizes the
need to critically examine and address its embedded biases, as it continues to grow. The
314 fieldwork-intensive nature of movement ecology often requires expensive technology, large
datasets, remote travel, specialised training, and computational skills and resources, all of which
316 can magnify extant biases.

318 Here, we (a biased sample of the movement ecological community; see supplement 1) describe
biases present within movement ecology. Our overall goals are to start a conversation on
320 rectifying bias in our community, and to present a case study that can be used by other sub-
disciplines within biology. We use four approaches to consider both perceived biases (looking at

322 uninformed and informed perspectives) and observed bias (considering two forms of bias at two
spatial scales). First, we quantify perceived biases by surveying attendees of a conference in our
324 sub-discipline. Next, to quantify the extent to which biases manifest, we assess data on observed
biases at two scales: among countries and within a specific country. Our among-country
326 observed bias approach quantifies patterns in countries where authors are based and where
research is conducted for articles published in the sub-discipline's primary journal. Our within-
328 country observed bias approach quantifies representation in the broader discipline of biology
with respect to race and gender identities of academic biologists in the United States. We then
330 summarise a conference-based discussion explicitly organised around these three findings
(survey results, international authorship patterns, within-country identity patterns), i.e., the
332 perceived bias informed by observed bias data. Finally, we contextualise the results within our
sub-discipline, identifying traits potentially driving the emergence of specific biases.

334

336 **Methods**

338 *Uninformed perceived bias: Pre-conference Survey*

340 To quantify perceived bias within the movement ecology community, we conducted an
anonymous email survey of attendees registered for an international conference in the sub-
342 discipline. The conference, held in Tuscany Italy in May 2023, was the third edition of a
thematic conference series on movement ecology of animals that primarily addresses an audience
344 of specialists in the sub-discipline. The attendees of these conferences are typically a mixture of

invited speakers and selected poster presenters, with diversity being a criterion of selection
346 alongside scientific excellence as per the conference series guidelines. The conference
participation is capped at 200 individuals; in 2023 it was attended by 196 people from 24
348 countries (2 countries in Africa, 5 in Asia, 2 in Oceania, 13 in Europe, 2 in North America; for
demographics over time see figure S1 in supplement 2). The conference fee exceeded US\$1300
350 (including accommodation and food, but not transportation). Some of this cost was offset for
some participants by conference grant funding. The survey was distributed via Qualtrics, an
352 online survey platform that meets human subjects research data security requirements (see
supplement 3). We used a mixed approach with both short-answer questions (harder to analyse
354 quantitatively but open-ended responses) and multiple choice questions (easier to analyse
quantitatively, but constrained responses). We asked registered attendees of the conference to
356 what extent they perceived bias in the community (Q1), what the main sources of bias were (Q2
short answer, Q3 multiple choice), which experiences their answers were based on (Q4), how the
358 community could become less biased (Q5), and who should be responsible for addressing bias in
the community (Q6). To generate the possible answers for Q3 on probable sources of bias, we
360 requested input from researchers of different backgrounds who work on movement ecology but
were not attending the conference. The study protocol was reviewed by the University of
362 Minnesota Institutional Review Board (IRB, which assesses the safety of research with human
subjects) in March 2023 and was determined to be exempt from further IRB review. We
364 distributed the survey to approximately 200 registered attendees via email on April 25th 2023
(with a reminder on May 10th 2023). A total of 135 survey responses were collected between
366 April 26th and May 24th 2023, prior to the conference. Survey responses were analysed
quantitatively for Q1, Q3, Q4 and Q6, and qualitatively for the open-ended questions (Q2, Q5).

368

Observed bias

370

International scale, geographic bias: Journal articles

372 To provide an example of observed bias (in researcher representation) at the international scale,
we analysed geographic patterns of authors' institutional affiliation and study location for articles
374 published in the open-access, flagship journal of our sub-discipline, *Movement Ecology*. On
January 21st 2023, we used Scopus to download article information (including the affiliations of
376 all authors and the address for correspondence) for all papers published in this journal to date.
There were 370 articles published between the journal's inception in 2013 to the data download
378 date. For each article, we extracted (i) the first country listed for the first author (i.e., their first
affiliation if more than one was listed), and (ii) the first country listed for the corresponding
380 author. We quantified the number of times each country appeared in each of these lists (first
author or corresponding author) for the full set of 370 articles, and looked at the distribution
382 among countries. For each article, we also determined whether the primary data used in the
article was newly collected for the study and, if yes, the country of data collection. For studies
384 that tracked animals that crossed international borders, we only included the country/territory
where the trackers were deployed. Of the 370 articles, 266 were considered to have collected
386 new data, while the other 104 were excluded from this part of the analysis because they were
corrections, review papers, meta-analyses, theoretical, or that used simulated or previously
388 published data. For consistency, we used country/territory names as they appear on the World
Bank list [36]. We used World Bank data [37] to get the most recently available yearly Gross
390 Domestic Product (GDP) data for each country where primary authors were based. We then

392 estimated the effects of yearly GDP on each country's yearly number of publications using a
Generalized Additive Model [38]. The model used a Poisson family of distributions and a log
link. The model included a smooth effect of $\log_{10}(\text{GDP})$ (as the distribution had a long right tail)
394 and a random intercept of country to account for country-level over-representation (model G
sensu Pedersen et al. [39]):

396

$n_papers \sim s(\log_{10}(gdp), k = 5) + s(\text{country}, bs = 're')$.

398

It was not possible to include random smooths for each country (model GS sensu Pedersen et al.
400 [39]) because a third of the countries in the dataset only had publications for one year. We also
used 2022 gross national income (GNI) levels from the World Bank Atlas [40] to classify
402 countries into different income levels: low income countries have a GNI of <\$1,135, lower
middle-income have a GNI between \$1,136 and \$4,465, upper middle-income have a GNI
404 between \$4,466 and \$13,845, and high income countries have a GNI over \$13,846. We grouped
countries into regions based on the World Bank list [36] and then created an alluvial plot, linking
406 each study from the institutional affiliation to the location of fieldwork using the *ggalluvial* R
package [41] (see also supplement 4).

408

Within-country scale: race and gender bias in USA biology researchers

410 To provide an example of observed bias (in demographic representation) at the within-country
scale, we analysed patterns of representation by race/ethnicity and gender across career stages of
412 academia and compared them to the general public for the United States of America (USA). We
chose the USA because it is a country that collects and publicly disseminates this demographic

414 data on a national scale. The USA is also the country with the most first authors of *Movement*
415 *Ecology* articles (n=120 of 370) analysed above. Since data is not available down to the sub-
416 discipline scale of movement ecology, we used the closest scale available: biology. We gathered
2021 data for graduate students and postdoctoral researchers [42] as well as faculty [43], and
418 census data for the USA general population for 2019 (the most recent data available) [44]). We
combined some race/ethnicity categories to facilitate comparison (see Table S2 in supplement 4).
420 All datasets categorised gender as a binary (male or female). For each group, we calculated the
proportion of individuals who identified in each gender-and-race combination (hereafter ‘race-
422 gender group’). For the graduate student and postdoc data, race/ethnicity was only collected for
individuals that are either USA citizens or permanent residents; so for these datasets we
424 calculated the proportion of individuals in each race-gender group as a portion only of the
number of USA citizens / permanent residents. For each race-gender group for each career stage,
426 we calculated the relative representation [45] as

$$\theta = \frac{P_{obs} - P_{cen}}{P_{obs}}$$

428 where p_{obs} is the observed proportion of a race-gender group within a career stage and p_{cen} is the
proportion of a race-gender group across the censused USA population.

430

Perceived bias informed by observed bias data: Conference Discussion

432

Finally, to assess observation-informed perceived bias, results of both the survey and the
434 observed bias approaches were presented and discussed at the previously mentioned conference
in a session on inclusion and barriers to inclusivity. The day before the session, all conference
436 attendees were provided a handout summarising the findings of the survey and the international

and within-country approaches (supplement 5) and were invited to attend the discussion. Of the
438 196 conference attendees, 105 participated in the discussion. Attendees were split into 10 groups
of 8-12 people. The discussion volunteer leaders described the goals of the session, presented an
440 overview of the findings, and provided groups with two sets of discussion prompts. Each group
identified a scribe to record notes. The groups discussed a first set of prompts (“In your words,
442 what do you think bias is? Before now, have you ever thought about bias in the movement
ecology community? What is surprising or interesting to you about the survey results?”), and
444 then reported back to the broader group. The groups then discussed a second set of prompts
 (“What is something you plan to do going forward? What should we discuss doing as a
446 community?”) and again reported back to the broader group. Notes from each group were
compiled by the discussion leaders, and summarised below, and everyone was invited to be a
448 potential co-author on this publication (see supplement 1).

450

Results

452

Uninformed perceived bias: Pre-conference Survey

454

Frequency and sources of bias

456 We received survey responses from 135 individuals out of approximately 200 distributed surveys
(although not all respondents answered every question). Nearly all survey respondents who
458 answered question Q1 (see supplement 3), believed that there was bias present within the
movement ecology community (96.8%, n = 90; Figure 1A). The majority of respondents rated

460 this bias as low (44.1%, n = 41, scores 1-2), whereas 20.4% (n = 19) of respondents perceived
bias as high (scores of 4-5). These patterns largely correlated with the respondent's own
462 experience of bias as identified in survey question Q3. Specifically, 55.6% (n = 25) of
individuals with no direct experience of bias perceived little to no bias within the community,
464 compared to 39.6% (n = 19) of individuals with personal experience of bias. Conversely, only
6.7% (n = 3) of individuals with no direct experience of bias perceived the community as highly
466 biased, compared to 33.3% (n = 16) of individuals with personal experience.

468 Survey respondents' own experience of bias influenced not only their perceived frequency of
bias, but also the sources of bias. In response to the open-ended question Q2 'What do you think
470 the main sources of bias are, if any?', the most commonly reported answers were biases
associated with who does the study (Table S1 in supplement 2). In response to a close-ended
472 question Q4, individuals with personal experience of bias reported the greatest number of
perceived sources of bias (n = 17) relative to those with no direct experience (n = 13) (Figure
474 1B). Overall, 'funding disparities', 'geographic concentration of researchers', 'taxonomic bias',
and 'BIPOC [Black, Indigenous, and other People of Color] underrepresentation' were
476 consistently reported as key sources of bias, accounting for 55.2% (n = 88) of the keywords best
capturing the sources of bias (see supplement 3 for full list of options in the survey). In contrast,
478 there were differences in perceived sources across groups with different experiences of bias. For
example, explicit categories of discrimination - 'sexism', 'racism', and 'classism' - accounted for
480 15.6% (n = 21) of keywords for individuals with direct experience of bias, ranking 5th, 7th, and
8th, respectively. However, 'sexism' and 'classism' were less perceived as sources of bias by
482 respondents with no personal experience of bias, with 'racism' not perceived as one of the top

three issues. Together, these data highlight the prominent role of personal experience in dictating
484 the perception of frequency and source of bias within a research community.

486 Reducing bias

Suggested strategies for reducing bias (Q5) ranged from interventions and actions targeted at the
488 individual level, for example elevating researchers from under-represented backgrounds, to the
institutional level, such as changing funding priorities (Table 1). Overall, public funding bodies,
490 universities, scientific societies, and individuals were most frequently mentioned as the entities
that should be involved in reducing bias (55.8% of keywords, n = 88, Q6) (Figure 1C). However,
492 whilst there was consensus among groups with different experiences of bias that public funding
bodies, scientific societies, and universities should be involved in reducing bias, most individuals
494 who had not personally experienced bias did not believe that individuals should be charged with
reducing bias.

496

498 *Observed bias*

500 International scale, geographic bias: Journal articles

The analysis of geographic bias at the international scale showed that countries were not evenly
502 represented in authors' national affiliations for articles published in the journal *Movement
Ecology*. Only 28 countries (<15% of global countries) were represented by first authors in the
504 journal (n = 370 articles; Figure 2). There were 120 first authors affiliated with the United States
of America, 40 with Canada, 40 with Germany, and 39 with the United Kingdom. All other

506 countries were represented by less than 20 first authors. The patterns were similar when looking
at the country of affiliation of the corresponding author (see Figure S2 in supplement 2).

508 Additionally, the average number of publications per year increased exponentially with yearly
Gross Domestic Product (GDP; an indicator of the size of a country's economy; see Figure 3,
510 Figures S3-S4 in supplement 2).

512 Most studies were conducted in the same geographic region as the first author's institutional
affiliation. Of the 266 articles that collected new empirical data, 78% of studies conducted
514 fieldwork in the same geographical region as the institution of the first author (Figure 4). For the
22% of the articles where the study site and first author affiliation were not identical, there were
516 some notable disparities. First authors with institutional affiliations in North America and Europe
had a higher tendency to conduct fieldwork in other regions when compared to first authors with
518 institutional affiliations in Asia, Africa, and Latin America. Most studies in Latin America were
conducted by researchers based at institutions in North America. Most studies in Africa were
520 conducted by researchers based at institutions in either North American or Europe with a fairly
even split between the two. Furthermore, most studies that took place in low and lower-middle
522 income countries were led by researchers with institutional affiliations in other regions (Figure 4,
red and green bars). For studies in upper-middle income countries, the pattern varied by region –
524 studies in Europe and Asia were conducted by researchers at institutions in those same regions
whereas studies in Africa and Latin America were conducted by researchers at institutions in
526 other regions (Figure 4, yellow bars).

528 Within-country scale: race and gender bias in USA biology researchers

Changing scales, we next analysed observed representational bias occurring at the within-country
530 scale for academics within the discipline of biology in the United States of America. We found
that representation of race-gender groups often differed from their representation in the general
532 USA population (Figure 5). White-male, Asian-male and Asian-female groups were all
overrepresented among biology faculty compared to the general population, while all other race-
534 gender groups were underrepresented. The most underrepresented race-gender group at all career
stages was Black / African-American men, with underrepresentation generally increasing across
536 career stages, and always lower than Black / African-American women. Within the race/ethnicity
identities of White, Asian, and Hispanic / Latino, women had higher representation than men
538 among graduate students but lower representation at the faculty level.

540

Perceived bias informed by observed bias data: Conference Discussion

542

In your words, what do you think bias is?

544 When asked to define bias in their own words, the participants gave a variety of answers that
described bias as an intentional (explicit, conscious) or unintentional (implicit, unconscious)
546 show of prejudice that can lead to systematic disparities in representation or opportunity. Bias
can encompass both outcomes and causes – both aspects emerged in the discussion although not
548 explicitly presented in the survey. Participants discussed that bias can result from misconceptions
and subjective viewpoints that are not supported by evidence, and may lead to differential
550 treatment of some individuals. People might be focused on their own ideas, perspectives and

experiences, tending to associate with other people who share similar identities or similar
552 circumstances (e.g., socioeconomic status). Further views underlined that bias can also result
from power imbalances (e.g., differences in academic rank), or confirmation bias. As a result,
554 other legitimate viewpoints arising from different experiences or values are either ignored or
rejected. Biased perspectives limit opportunities for some individuals, and can therefore result in
556 reduced representation, leading to overall reduced diversity. These disparities can have
consequences that manifest in a variety of ways, from psychological well being (e.g., feelings of
558 unworthiness or imposter syndrome) to support for research (e.g., limited access to funding).

560 Before now, have you ever thought about bias in the movement ecology community?

Effectively all discussion participants reported having thought about bias within our community.
562 The specific biases on which discussions focused spanned demographic, geographic, and
methodological. The community is aware of demographic biases that exist among its members.
564 The conference attendees, the majority of whom are from (or are working in) Western nations
(Figure S1 in supplement 2), acknowledge that the sub-discipline continues to be dominated by
566 white men, and that possibilities for career progression are not distributed equitably across
gender and race identities. A significant point of concern was geographical bias due to the
568 shaping of ideas, research paradigms, and methodologies being predominantly driven by
scientists in North America and Europe. The costs associated with publishing in open-access
570 journals, attending international conferences, and utilising advanced research technologies (e.g.,
bio-logging devices) were thought to be major contributors of geographic bias through their
572 disproportionate impacts on researchers, research topics, and methodologies (e.g., sample size)
from countries with lower GDP. An additional concern was the prevalence of “parachute or

574 helicopter science” where researchers from these regions descend on regions with lower GDP,
often sidelining local scientists, failing to give credit to local communities and missing
576 opportunities for skill transfer, local capacity building, and knowledge exchange. Regarding
research itself, biases affect methodology and topics. For example, research frequently favours
578 popular or ‘charismatic’ species, while neglecting less well-known ones.

580 What is surprising or interesting to you about the survey results?

Multiple groups remarked on how closely the outcomes of the survey aligned with their
582 expectations. Many of the groups discussed geographic biases underlying these results and were
interested in how the data on the affiliations of first authors in the journal *Movement Ecology*
584 would differ from the locations of data collection or the authors’ countries of origin. [Based on
this discussion point, we extracted more information from the articles to make this comparison –
586 described above, and presented in Figure 4]. Some noted that the emphasis on geographic bias
might be due to the composition of the survey pool, since many respondents referenced their own
588 personal experience as evidence.

590 What is something you plan to do going forward?

Suggestions for actionable next steps ranged from changing individual perspectives, to exerting
592 pressure to change community culture, to making needed policy changes to the academic system.
Changing individual perspectives might require taking responsibility to acknowledge and
594 mitigate one’s personal biases, identifying power dynamics, understanding the needs and the
perspectives of others, and acting on bias when witnessed. Several participants mentioned that it
596 is hard to fight bias on their own, suggesting the need for collective action by peers and

colleagues. Ideas for changes in behaviour differed across academic stage. More senior
598 researchers indicated the need to involve people from the global community, to increase
mentorship of underrepresented communities, and to increase exchange opportunities for
600 international students to obtain experience and training and to grow their professional networks.
More junior researchers suggested the need to identify and reduce geographic and gender bias in
602 citations used in academic publications. More outreach is needed to show opportunities that are
available in the sub-discipline of movement ecology, and it is important to start diversity and
604 equity groups (including reading groups) to raise awareness of bias in our sub-discipline. For
peer-reviewing, considerations on the quality of the English writing should be separated from
606 main comments (most journals offer a section for that), and constructive comments should
account for potential sources of bias authors from underrepresented groups could be exposed to.
608 Discussions highlighted that conference attendees were mostly native English speakers. It was
also underlined that cheaper, more inclusive conferences are needed to promote change (e.g., by
610 hosting conferences in the Global South or by offering formative opportunities such as
workshops). While some solutions, such as waiving conference or publishing fees, have
612 sometimes been implemented, they are largely financial in nature and do not adequately address
the full scope of the biases identified. For example, past efforts to increase the diversity of
614 conference attendees by making funding available have fallen short (i.e. not many applications
for conference scholarships from members of underrepresented groups are submitted). It was
616 also noted that although each suggested action addresses a small part of the problem, together
they will hopefully collectively improve inclusiveness within the community.

618

What should we discuss doing as a community?

620 When participants were asked what we should discuss doing as a community in response to the
problems associated with bias in the sub-discipline of movement ecology, solutions were
622 proposed that can broadly be categorised as relating to funding agencies, publishing, conference
organisation, and community environment. That said, in many groups, there was frustration
624 about the inefficacy of anti-bias efforts in creating desired change. The issue of funding was
discussed at length, including limitations associated with funding agencies, peer-reviewed
626 journal costs and conference fees. For example, geographic restrictions are often imposed by
funding agencies, by which only people from a certain country can access funds. For instance,
628 national funding to support conference attendance may sometimes only be used for scholars
affiliated with institutions in that country. Several groups suggested encouraging senior
630 researchers to leverage their role to do anti-bias work, such as by using relationships with
tagging companies to secure more funding for scholarships. In terms of peer-reviewed
632 publications, some comments were made about limitations associated with research costs and to
what extent this should be accounted for by reviewers. Other solutions included the publication
634 of abstracts in peer-reviewed papers in languages other than English, double blind peer-review,
focusing on inclusivity in invitations to publish in journal special issues and increased
636 accessibility of data, code and tutorials. Similarly, choosing more affordable conference venues,
considering visa issues, or supporting virtual attendance may promote broader representation.
638 Additionally, increasing the availability of funding targeted at increasing attendance by
underrepresented groups could be beneficial. It was also recommended that the perception of
640 exclusivity should be reduced, that rules around the diversity of chairs, speakers and panelists
should be evaluated, and that each specific conference should rotate locations to increase

642 accessibility from a greater diversity of geographic regions. Others suggested that in order to
ensure that underrepresented communities are not disproportionately burdened with solving
644 problems of bias, people from majority groups should increase their engagement in anti-bias
work. Other proposed solutions included changes in attitudes, such as more listening and
646 learning, i.e. making spaces more welcoming for underrepresented groups to speak up and be
heard. It was also recommended that for future conferences in our sub-discipline we bring in a
648 professional with expertise in diversity and equity to suggest actionable changes.

650

Discussion

652

Here, we studied bias in a scientific community (i.e. science of science; [46]), mainly by
654 characterising sources of observed and perceived bias within the sub-discipline of movement
ecology as a case study. Our purpose was to explicitly bring a topic that is often implicit to the
656 forefront, by quantifying patterns, understanding what factors shape conclusions on these aspects
within our community, and providing motivation to broaden participation and inclusiveness in
658 our sub-discipline.

660 We quantified **observed bias** at two spatial scales and in two different forms: among-country
discrepancies in where authors publishing in *Movement Ecology* are based and where data are
662 collected, and within-country discrepancies in race/ethnicity and gender identity of biology
academics compared to the general public of the USA. The first set of findings aligns with
664 parachute science [47], which although sometimes supported by alleged good intentions, can fuel

bias when not transformative beyond the single research project [48]. Also, it may indicate GDP-
666 skewed research investments on this particular discipline. This second set of findings recovers
some previously described results with respect to single axes of identity; i.e., that the
668 representation of women decreases across academic stages and that Black / African-American
and Hispanic / Latino identities are consistently under-represented within academia in the USA
670 [12,45]. However, our findings also highlight places where considering multiple axes of identity
together can provide new insights – i.e. that scale matters. Thus, care should also be taken in
672 extrapolating our findings across scales; the within-country dataset is simultaneously more
narrow (within the USA vs across countries) and more broad (all of biology vs movement
674 ecology) than the first dataset, and biases present at one scale may not be present at others (e.g.
[49]).

676

We examined **perceived bias** and found that it differed by context. For example, all conference
678 discussion participants reported having previously thought about bias in movement ecology
(informed perceived bias), while our pre-conference survey showed a wide range of perceived
680 degree of bias (uninformed perceived bias, Figure 1A). Many of the themes raised in our
discussions are aligned with those that have emerged in other discussions of STEM
682 subdisciplines underpinned by fieldwork research [50,51]. Furthermore, the same sources of bias
were not highlighted in both the survey and discussion. For example, both focused on geography,
684 but the informed discussion focused less on race and gender. Specifically, for the open-ended
survey question, the most common responses were gender/sexism and race/ethnicity/racism as
686 key sources of bias (Table S1 in supplement 2). However, for the multiple choice survey
question, survey takers did not select ‘racism’ as a key source of bias, but they did select ‘BIPOC

688 underrepresentation’ and ‘geographic concentration of researchers’. Survey participants who did
select ‘racism’ as a key factor were exclusively those who drew on their personal experience to
690 answer the survey (Figure 1B). During the discussion (informed by the survey data), this pattern
on sources of bias was amplified with little (if any) discussion of racism but extensive discussion
692 of geographic and socioeconomic factors. One interpretation of these findings is differential
comfort in discussing different sources of bias, especially in group settings. However, we
694 recognize that perception shapes discussions. Thus, our discussion of perceived bias was shaped
by the participants (supplement 1); a different set of movement ecologists may have had a very
696 different discussion about bias.

698 Our quantitative analysis of observed and perceived bias generated a number of ideas for future
quantitative research on bias. First, one could use a different classification scheme or look at a
700 different spatial scale to consider the link between economic activity and publications. Further
research should explore the disconnect we discovered between country affiliation of researchers
702 and countries where the research is done. Although we focused on first and corresponding
authors, one could test whether the patterns change by considering affiliation of senior authors.
704 For papers with more than two authors, one could examine the diversity of middle authors’
affiliations, and whether it matches the affiliation of the first and last authors. This should be
706 done with care as a higher diversity of countries of affiliation could be seen as positive (i.e.
promoting international collaborations) or negative (i.e. relegating researchers who support local
708 fieldwork as middle authors, rather than as leads). Some authors also had several affiliations
from countries with different geographic and economic contexts, leaving unclear what portion of
710 the research (e.g., data collection/analysis, PhD awarding, financial support) happened in which

country. Second, future work could quantify biases in other aspects of identity that were not
712 addressed by our work, especially ones where safety and physical constraints can impede travel
(e.g., LGBTQIA+ identity, disability, caregiving).

714

The approach we used here could also be applied to other disciplines such as archaeology,
716 geology, and anthropology that obtain data with fieldwork. We could also compare our findings
with other sub-disciplines of biology to see where biases are similar and different. For example,
718 movement ecology may have more financial driven bias than some sub-disciplines (e.g., by
requiring expensive equipment, logistics and travel) or less than others (e.g., those that rely on
720 large infrastructure such as genomics labs). Further, fieldwork can have differential impacts on
researchers based on the researcher's identity [52], the interaction with stakeholders [53], or the
722 cultural context.

724 Quantifying bias does little to move the conversation forward without a call to action. A shared
comment during the conference discussion regarded the need for proactive measures to elevate
726 voices and engage groups, so that people with all perspectives/backgrounds are present where
science is being discussed and conversations on how to strengthen our communities are taking
728 place. Survey takers also suggested a number of actionable solutions (Table 1). A core part of
addressing these biases is financial: the distribution of research funds is unequal (both globally
730 and within countries) and exacerbates existing biases. Some of these are norms that can be
addressed within our community (e.g. discouraging pay-to-play opportunities, paying researchers
732 fair wages, exploring cheaper research approaches) while others require systemic change (e.g.
global redistribution of funding towards underrepresented groups). Some actions could benefit

734 from bringing in researchers from sociology, psychology and other specialised disciplines to
provide structured recognition and mitigation of bias. For example, future work could consider
736 how different forms of bias may affect one another or be correlated, and so contemporarily
emerge.

738

Conclusion

740 Bias is omnipresent in science and we need to understand how biases develop and persist in
order to proactively broaden representation. One advantage of our data-driven, community-based
742 approach is that we can now monitor the impacts of this work at the community level (i.e., if and
to what extent these conversations have been improving our community since their onset). While
744 presenting a partial view on bias in our community, we were able to identify some critical
starting points that are particularly relevant to the sub-discipline (e.g., geographic and economic
746 bias). While identification of concrete actions to address these drivers is at its infancy, we see a
proactive attitude towards the risk of bias to be part of the solution.

748

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906 **Table 1.** Responses to the open-ended survey question [Q5] ‘How do you think the Movement
 Ecology community could become less biased?’, organised into broad categories. Of 135 survey
 908 takers, 61 answered this question.

Strategy type	Details	# Participants suggesting
Personnel	<ul style="list-style-type: none"> * Training opportunities (target by country, target underrepresented groups) * Collaboration/knowledge sharing (across fields, taxa, perspectives, regions, communities, Indigenous perspectives) * Elevate researchers from under-represented backgrounds * Better advising (more inclusive, acknowledge trainees) 	26
Scientific process	<ul style="list-style-type: none"> * Methodological approaches (stronger framing + less descriptive methods, technological advances, more observation, synthesis, targeted experiments) * Systems studied (increase geographic and taxa diversity) * Publication process (reduce bias in review, more geographic opportunities) * Changing norms (less gatekeeping, publication prestige, what is funded, publication language, make data/outputs available) 	22
Financial	<ul style="list-style-type: none"> * Increase equity by geography, income, career stage, or other axes with disparities * Funding to increase diversity of systems and perspectives 	22

	<ul style="list-style-type: none"> * Paying fair wages / discouraging pay-to-play * Lower research costs / cheaper equipment 	
Events, action, other	<ul style="list-style-type: none"> * Conversations (discussions about culture shift, raise awareness of bias, acknowledge power disparity) * Learning (study our biases, learn science history, understanding of bias by people in power) * Events (networking opportunities, technical workshops, increase inclusivity of conference and events) * Special journal issues on movement ecology * Policies (inclusive ones generally, job flexibility, more jobs) 	16

910 **Figure 1.** Summary of survey responses from participants of an international conference in
 movement ecology split by individuals' own experiences of biases. Responses cover the
 912 questions of (A) bias within the movement ecology community (0 is unbiased, 5 is very biased),
 (B) sources of bias, and (C) entities that should be involved in decreasing bias. Individual's
 914 responses were based on one of three categories: speculation (yellow), external evidence such as
 readings (grey), and personal experience (green).

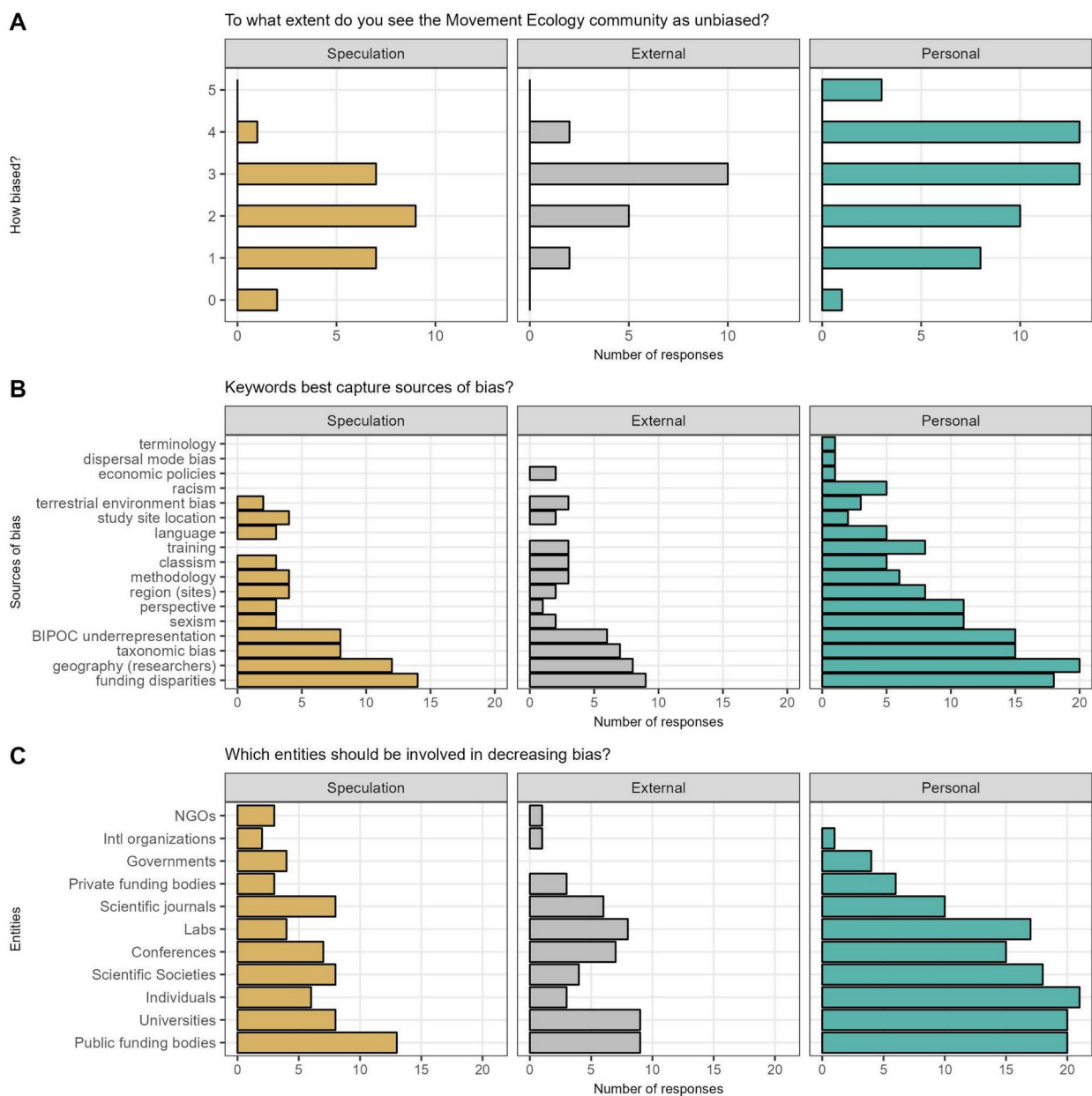


Figure 2. The number of times each country was listed as the first author's first affiliation for all 918 370 articles published in the journal *Movement Ecology* from its launching in 2013 until January 2023.

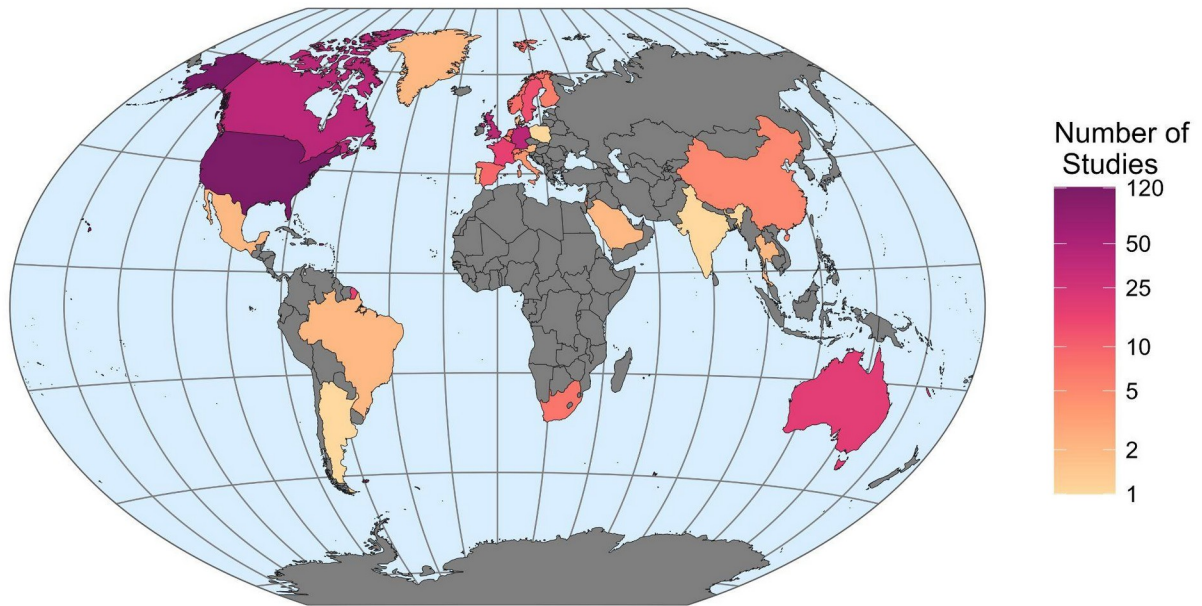


Figure 3. Publication rate depends strongly on a country's gross domestic product. The relationship between a country's GDP and the number of times it was listed as the first author's first affiliation across (left) all 370 articles and (right) the 266 articles with new and empirical primary data, published in the journal *Movement Ecology* from its launching in 2013 until January 2023. The black line indicates the estimated relationship, while the grey shaded areas indicate the 95% Bayesian credible intervals.

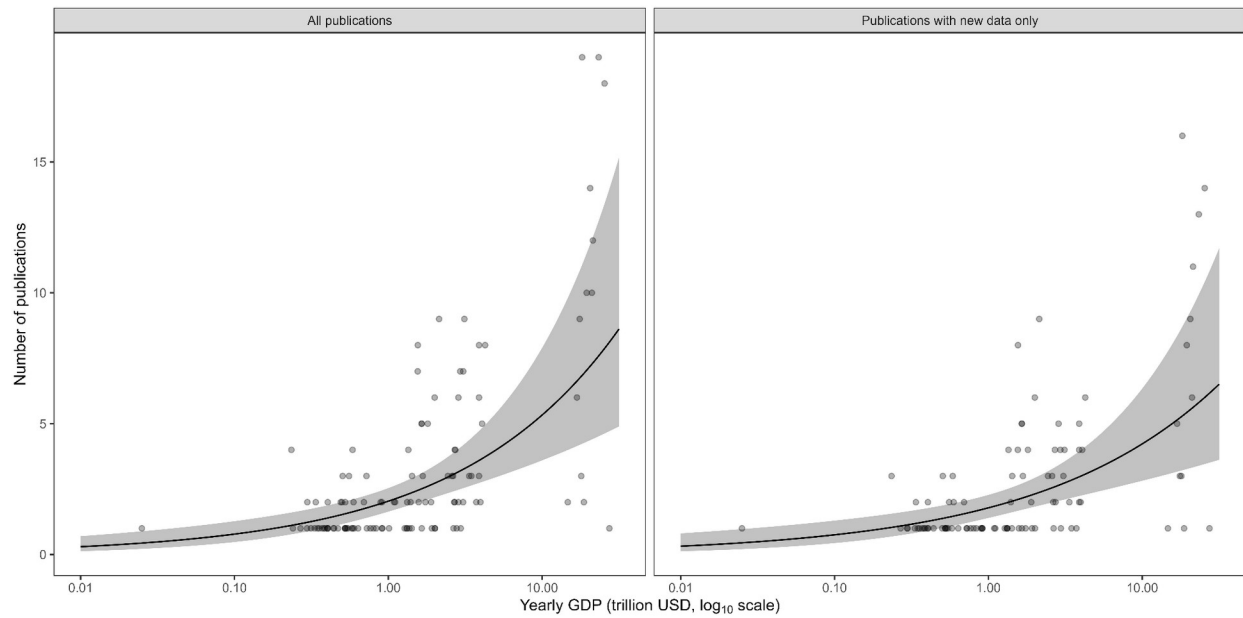


Figure 5. The relative representation of USA life science researchers across 3 career stages that provided race and gender information. Positive values indicate a group is overrepresented compared to the USA population (as reported in the USA census) and negative values indicate a group is underrepresented. The race/ethnicity, gender, and career-stage categories included in this figure were specified in the surveys and census. Race/ethnicity categories included American Indian and Alaska Native, Asian (including Pacific Islander), Black and African American, Hispanic and Latino, and White. Note however that data on American Indian and Alaska Native faculty were not reported. Gender categories included only female (squares) and male (circles). Data available on career-stages included faculty (yellow), postdoctoral researchers (green) and graduate students (blue, but were only reported for USA citizens and permanent residents).

