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LGBTQ+ Realities in the Biological Sciences

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ABSTRACT

While scientific environments have been described as unwelcoming to the LGBTQ+ community, and fields such as physics have systematically documented these challenges, the climate in biology-specific workplaces has not exclusively been assessed. We conducted the largest survey to date of LGBTQ+ biologists to examine how their sense of belonging and perception of climate in the biology workplace and professional societies compare to that of their straight and cis peers. In 2023, we surveyed 1419 biologists across five professional societies, with 486 identifying as LGBTQ+. Trans and gender non-conforming (TGNC) biologists reported lower belonging and morale within the workplace, professional societies, and the biology community compared with cis, straight biologists. They also reported being less comfortable with the climate of various professional biology environments. While LGBTQ+ biologists report that their workplaces are moderately inclusive, over 20% of all LGBTQ+ biologists and nearly 40% of TGNC biologists experience exclusionary behavior at work. This landmark survey provides the first comprehensive analysis of the LGBTQ+ climate in biology, revealing specific challenges faced by TGNC scientists.

INTRODUCTION

Science, technology, engineering, and mathematics (STEM) fields, including biology, have been documented to be hostile and discriminatory environments for LGBTQ+ individuals (Cech and Pham, 2017; Cech and Waidzunas, 2021; Vaccaro *et al.*, 2021;

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Reggiani *et al.*, 2024; Marosi *et al.*, 2025). The term LGBTQ+[1] is meant to include any individual who does not identify as straight or cisgender, including people who identify as lesbian, gay, bisexual, transgender, queer, and questioning. LGBTQ+ scientists are likely underrepresented and underserved in STEM (Busch, Araghi *et al.*, 2024; A. A. Casper, Atadero *et al.*, 2022; Hughes, 2018; Maloy *et al.*, 2022), yet some scientific organizations do not consider LGBTQ+ individuals to be members of an underrepresented group (Freeman, 2020).

The unwelcoming nature of STEM has been attributed to the pervasive cisheteronormativity (Bilimoria and Stewart, 2009; Cech and Waidzunas, 2011; Human Rights Campaign, 2018; Leyva, McNeill, and Duran, 2022; Marosi *et al.*, 2025), defined as the distinct yet interconnected relationship between heterosexual and cisgender privilege involving prejudice toward non-heterosexual identities and gender nonconformity (Marchia and Sommer, 2019). In addition, STEM spaces have been shaped by the cultivation of an ostensibly apolitical culture that sidelines diversity issues (Cech, 2013; Cech and Waidzunas, 2021; Hughes and Kothari, 2023; Mattheis *et al.*, 2019). Often under the guise of retaining objectivity, by keeping identities (including discussions about sexuality or gender) out of STEM, STEM fields effectively become "queer-free," in contrast to "queer-friendly" social sciences (Bilimoria and Stewart, 2009; Forbes, 2022; Mattheis *et al.*, 2019). Studies have documented that STEM faculty may keep their LGBTQ+ identities concealed out of fear or concern about the appropriateness of sharing the identity (Bilimoria and Stewart, 2009). Further professionalism in STEM is frequently conflated with hiding or "toning down" one's LGBTQ+ identity (K. J. Anderson and Kanner, 2011; Bilimoria and Stewart, 2009, p. 90; Russ *et al.*, 2002).

There have been some efforts to systematically assess the experiences of LGBTQ+ individuals in professional STEM environments. Patridge and colleagues surveyed 279 LGBTQ+ STEM faculty in 2010 and found that 45% of faculty were comfortable on their campus, in their department, and in their classroom, compared with 55% who were uncomfortable in at least one location. In 2013, Yoder and Mattheis surveyed over 1000 LGBTQ+ individuals working across STEM careers (including graduate students, non-academics, and faculty) and found that most participants rated their workplaces as safe; indeed, most participants reported that their workplace was either welcoming to LGBTQ+ individuals or treated them equally to non-LGBTQ+ individuals (Patridge *et al.*, 2014; Yoder and Mattheis, 2016). However, the most recent large-scale study in 2021 concluded that LGBTQ+ STEM professionals experience career limitations, harassment, and professional devaluation to a greater extent than their non-LGBTQ+ peers (Cech and Waidzunas, 2021).

Unwelcoming STEM spaces subject LGBTQ+ individuals to social and professional exclusion, through experiences of invisibility, oppression, marginalization, and harassment (Marosi *et al.*, 2025; Vaccaro *et al.*, 2024). An array of studies has described the specific challenges that LGBTQ+ individuals face across STEM fields. For example, physicists reported experiencing discrimination due to their LGBTQ+ identities (Barthelemy *et al.*, 2022), LGBTQ+ individuals working in interdisciplinary environmental science teams reported being disrespected by their peers (Cech *et al.*, 2021), and LGBTQ+ STEM professionals reported negative workplaces, being devalued by their colleagues, feeling socially excluded, and interpersonal marginalization (Cech and Pham, 2017; Cech and Waidzunas, 2022, 2021). Notably, negative experiences are often intensified for LGBTQ+ individuals with multiple marginalized identities in STEM (Cech, 2022; Leyva, 2025; Leyva, McNeill, Balmer *et al.*, 2022; Leyva, McNeill, and Duran, 2022).

Science discipline-specific climate assessments are rare, with the 2016 LGBT Climate in Physics Report (Atherton *et al.*, 2016) being a notable exception. This study of 324 LGBTQ+ physicists, conducted in 2015, concluded that the climate experienced by LGBTQ+ physicists was highly variable. Social norms often established expectations for physicists to conceal their queer identities, and many scientists reported feeling isolated and experiencing or observing exclusionary behaviors toward LGBTQ+ individuals in the workplace. Additional studies have suggested that LGBTQ+ individuals' experiences may differ across STEM fields. For example, a study of over 1400 individuals across STEM fields found that LGBTQ+ individuals in earth sciences, engineering, and psychology reported being less out to colleagues compared with individuals in the life sciences and social sciences (Yoder and Mattheis, 2016). Considering the cultural differences among STEM fields and varying efforts to create inclusive environments, there is a pressing need for discipline-specific evaluations of LGBTQ+ climate.

The life sciences provide a particularly important context in which to assess LGBTQ+ climate, given the potential intersection of biology content and LGBTQ+ identities. Many biologists regularly encounter pervasive myths regarding the biology of attraction, biology of gender, genetics, reproduction, hormones, and sexuality, and may be expected to teach content that has been historically influenced by binary and cisheteronormative thought (A. P. Anderson and Falk, 2023; Beukeboom and Perrin, 2014; A. A. Casper, Rebolledo *et al.*, 2022; A. M. A. Casper *et al.*, 2025; Cooper *et al.*, 2020; Gorelick *et al.*, 2017; Leonard, 2019; Massa *et al.*, 2023; McLaughlin *et al.*, 2023; Roughgarden, 2013). Studies have highlighted sex and gender essentialism in textbooks (Bazzul and Sykes, 2011; Donovan *et al.*, 2024; J. K. Jackson *et al.*, 2024; Spaulding and Fuselier, 2023) and explicitly noted the absence of LGBTQ+ representation (King *et al.*, 2021). Interview studies have found that some LGBTQ+ undergraduates (A. A. Casper, Rebolledo *et al.*, 2022; Cooper and Brownell, 2016) and graduate students (Maas *et al.*, 2024) describe biology classrooms and graduate programs as unwelcoming and unaccepting spaces and some LGBTQ+ biology professors highlight the potential for negative repercussions if they were to reveal their identity within their department (Busch, Bhanderi *et al.*, 2024; Cooper *et al.*, 2019). The intersection between content and LGBTQ+ identities in biology creates potential tension points but also uniquely positions the biology community to lead changes to make STEM more inclusive. In fact, scholars have called for cultural changes in the values and norms in the life sciences, with the intent to improve equity in life science education regarding sex, gender,

[1]The + in LGBTQ+ is meant to encompass any gender or orientation minority identity that is not listed within the acronym. Identities often represented in the plus include, but are not limited to, intersex, asexual, pansexual and nonbinary.

and reproduction (A. M. A. Casper *et al.*, 2025). However, no large-scale studies have specifically probed the experiences of LGBTQ+ biologists as it relates to their work environments and professional societies.

The experiences of trans and gender non-conforming (TGNC) biologists are particularly important to understand, given that TGNC individuals encounter more extreme harassment, discrimination, and violence than their cis LGBQ counterparts (Coburn *et al.*, 2025; Devís-Devís *et al.*, 2022; Sears *et al.*, 2021). In biology, there are unique ways in which TGNC identities intersect with biology curriculum; namely, gender is often discussed in ways that erase or marginalize noncisnormative identities (A. A. Casper, Rebolledo *et al.*, 2022; Coburn *et al.*, 2025; Driessen *et al.*, 2024; D. Jackson *et al.*, 2024). An interview study of TGNC biology students revealed that biology can be implicitly exclusionary and negatively affect their sense of belonging, career preparation, and interest in biology content (A. A. Casper, Rebolledo *et al.*, 2022). However, there is a paucity of research that considers gender beyond the binary (Hyde *et al.*, 2019), particularly when studying the experiences of biologists (Coburn *et al.*, 2025).

The current study represents the first large-scale, biology-specific investigation of LGBTQ+ individuals, designed to distinguish the experiences of TGNC individuals from those of cis LGBQ individuals and non-LGBTQ+ individuals. We selected outcomes, including comfort, inclusion/exclusion, experiences with intimidating, offensive, and/or hostile conduct, and outness, to align conceptually with the discipline-specific climate study of LGBTQ+ physicists (Atherton *et al.*, 2016), enabling cross-disciplinary and temporal examination of our findings. Further, we build upon an in-depth literature review of 24 empirical studies published before 2022 that summarized LGBTQ+ experiences in STEM learning and working environments concluding that individuals' experiences are influenced by STEM culture (e.g., beliefs, values, and attitudes), interpersonal experiences (e.g., discrimination, harassment, exclusion), and individual experiences (e.g., emotions, burdens; Marosi *et al.*, 2025). The current study addresses each theme by investigating biology culture (perceptions of inclusion, exclusion, and climate), biology interpersonal experiences (experiences with exclusionary, intimidating, offensive, and/or hostile conduct, bias, and discrimination), and biology individual experiences (feelings of belonging, morale, and outness). We hope that this work can be leveraged by the readers of CBE Life Sciences Education, who often identify as both biologists and educators, since they are uniquely positioned to instill a more inclusive biology culture for LGBTQ+ individuals that will permeate biology workplaces, including universities, professional societies, and the biology community more broadly.

The following research questions guided this study: 1. To what extent do the belonging, morale, and comfort of LGBTQ+ and non-LGBTQ+ biologists differ regarding the field of biology, their professional societies, and their workplace? 2. To what extent do LGBTQ+ individuals perceive their biology workplace to be inclusive/exclusive? 3. To what extent do LGBTQ+ biologists experience or witness exclusionary, intimidating, offensive, and/or hostile conduct at work and outside of work? 4. To what extent do LGBTQ+ biologists experience bias and discrimination in the biology community? 5. To what extent are LGBTQ+ individuals out in different biology environments? 6. What recommendations do LGBTQ+ biologists have for creating more inclusive biology environments? When answering our research questions, we distinguished between the unique experiences of cis LGBQ and TGNC biologists.

MATERIALS AND METHODS

This study was approved by the Arizona State University Institutional Review Board (Protocol no. 18027).

Experimental design and survey development

To answer our research questions, we developed a survey with closed-ended and open-ended questions. A full copy of the survey questions is provided in Supplemental Materials. When possible, we aimed for conceptual alignment with the American Physical Society (APS) LGBTQ+ climate in physics study (Atherton *et al.*, 2016). We assessed comfort with climate, inclusive and exclusive workplace climate, experience with exclusionary, intimidating, offensive, and/or hostile conduct, and outness using items from the APS LGBTQ+ climate in physics survey (Atherton *et al.*, 2016; Barthelemy *et al.*, 2022).

However, the APS survey had few measures of individual experiences, a key component of LGBTQ+ biologists' comprehensive experiences (Marosi *et al.*, 2025). As such, we adapted the Course Cohesion Scale (Bollen and Hoyle, 1990) to measure sense of belonging and feelings of morale within the biology community, professional societies, and workplaces. We selected this scale because it emphasizes individuals' perceptions of their standing within a group (Bollen and Hoyle, 1990). We measured perceived bias and discrimination against LGBTQ+ individuals in science by modifying a scale previously developed to assess bias against religious individuals in science (Barnes *et al.*, 2020), and we developed two new questions to assess LGBTQ+ individuals' recommendations for making their professional societies and workplaces more inclusive. For each scale, we calculated Cronbach's alpha to test for repeatability (reported in the main body of the text) and a confirmatory factor analysis (CFA) for internal consistency (reported in the Supplemental Materials).

Sense of belonging and feelings of morale. The Course Cohesion Scale (Bollen and Hoyle, 1990) consists of two subscales—sense of belonging and feelings of morale—which each include three items. Participants respond to items on an 11-point Likert scale from strongly disagree (0) to strongly agree (10). We created aggregate scores for biology, professional society, and workplace sense of belonging and feelings of morale by calculating the mean of the three items. In our sample, we had excellent internal consistency for biology sense of belonging (Cronbach's $\alpha = 0.96$) and feelings of morale (Cronbach's $\alpha = 0.91$), society sense of belonging (Cronbach's $\alpha = 0.93$–0.97) and feelings of morale (Cronbach's $\alpha = 0.90$–0.93), and workplace sense of belonging (Cronbach's $\alpha = 0.96$) and feelings of morale (Cronbach's $\alpha = 0.93$).

Climate comfort. We assessed comfort with climate across professional and academic contexts using a single item per

context (Atherton *et al.*, 2016). Specifically, participants used a 5-point Likert scale ranging from very uncomfortable to very comfortable to rate how comfortable they were with the climate in 1) their campus or company, 2) department or division, 3) research lab or group, 4) classroom where they are an instructor, and 5) classroom where they are a student.

Demographic questions. Participants then answered a series of demographic questions regarding their gender, race/ethnicity, LGBTQ+ identity, current professional position (e.g., graduate student, university faculty), and current region of residence. The questions assessing LGBTQ+ identity captured both "LGBTQ+ identities referring to sexuality and/or romantic attraction" as well as "gender identity." Participants could select as many identities as applied and write an identity that was not listed. The questions were iteratively reviewed and revised by all LGBTQ+ authors, which included experts in biology education and LGBTQ+ research. After the questions were reviewed by the research team, they were also reviewed by an external group of LGBTQ+ biology education researchers who confirmed the questions were appropriate for our research purposes.

LGBTQ+ specific questions: Inclusive and exclusive workplace climate. LGBTQ+ participants rated 20 items based on how well they described the atmosphere for LGBTQ+ employees at their workplace, including 12 positively-worded inclusive climate items and eight negatively-worded exclusive climate items (Atherton *et al.*, 2016; Barthelemy *et al.*, 2022). We created aggregate scores for both the inclusive climate and exclusive climate measures by taking the mean of the respective items. We found excellent internal consistency for these measures in our sample for both inclusion (Cronbach's $\alpha = 0.93$) and exclusion (Cronbach's $\alpha = 0.91$).

LGBTQ+ specific questions: Experienced or witnessed exclusionary, intimidating, offensive, and/or hostile conduct. Using a series of questions (Atherton *et al.*, 2016), we assessed whether participants had experienced and/or witnessed any exclusionary (e.g., shunner and ignored), intimidating, offensive, and/or hostile conduct (harassing behavior) at their department or workplace. We also probed whether participants had experienced exclusionary (e.g., shunner and ignored), intimidating, offensive, and/or hostile conduct (harassing behavior) outside of their department or workplace.

LGBTQ+ specific questions: Perceived bias and discrimination. LGBTQ+ individuals in science rated four items assessing perceived bias and discrimination on a scale from strongly disagree (1) to strongly agree (7; Barnes *et al.*, 2020). We created an aggregate score by taking the average of the four items. Our sample demonstrated good internal consistency (Cronbach's $\alpha = 0.90$).

LGBTQ+ specific questions: Outness. To determine the extent to which LGBTQ+ participants are open about their identities in various contexts, they received a 5-point scale from not out (1) to out (5) to describe the extent to which they typically revealed their LGBTQ+ identity to: friends, immediate family, extended family, coworkers, research group, graduate courses, undergraduate courses, and broader community. Participants had the option to select N/A if they did not interact with a particular group of individuals (e.g., they did not teach graduate courses).

LGBTQ+ specific questions: Recommendations. To assess what common recommendations LGBTQ+ individuals had for making their professional societies and workplaces more inclusive, the author team developed two questions asking "What, if anything, could your respective professional society/societies do to make you feel more included as an LGBTQ+ individual?" and "What, if anything, could your workplace do to make you feel more included as an LGBTQ+ individual?"

Language and participant grouping

Throughout the analyses, we include any participant who indicated that they were a part of the LGBTQ+ community as "LGBTQ+." In analyses, we considered cisgender LGBQ biologists separately from TGNC biologists. The "cis LGBQ" group comprises participants who selected an orientation identity (e.g., lesbian, gay, and bisexual) and identified as cisgender. The "TGNC" group comprises participants who did not identify as cisgender, including those identifying as agender, genderqueer, gender nonbinary, or transgender. Individuals within the TGNC group may also hold orientation identities. This distinction enables the identification of challenges unique to different segments of the LGBTQ+ community.

Assessment of survey content and face validity

To assess content validity, or the extent to which individual items capture a construct's content domain (e.g., bias and morale), three LGBTQ+ biology education researchers with LGBTQ+ research expertise reviewed the full survey (Allen *et al.*, 2023). Based on their expertise and lived experience, they did not see reason to make any changes to the measures described above. To assess face validity, or whether the intended audience found the intended items understandable, relevant, and easy to answer, each question was carefully reviewed by 19 LGBTQ+ identifying biologists, including people who identify as cis LGBQ and TGNC (Allen *et al.*, 2023). Anytime a question did not meet these criteria, it was revised and iteratively reviewed by the group. Next, the full survey was reviewed by five LGBTQ+ identifying biology education researchers, some of whom are experts in LGBTQ+ biology education research. Minor changes were made to the survey before it was distributed.

Evaluation of measurement models

In addition to using Cronbach's α to demonstrate internal consistency, we conducted CFAs using the lavaan package in R (Rosseel, 2012) to verify the internal structure of each of the measures. Because sense of belonging and feelings of morale are subscales of a cohesion scale (Bollen and Hoyle, 1990), we ran a single CFA for workplace belonging and morale, with two correlated factors. We ran parallel CFAs for biology belonging and morale, and society belonging and morale. For the remaining scales (i.e., LGBTQ+ discrimination, LGBTQ+ inclusion, and LGBTQ+ exclusion), we ran one CFA per scale with all items loading onto a single factor. We used model

fit indices (CFI, TLI, RMSEA, and SRMR) to assess model fit. Supplemental Table S1 includes the model fit indices for each of the scales. For some scales, the RMSEA values were elevated, which is expected for models with low degrees of freedom (Kenny *et al.*, 2015). All scales demonstrated good model fit, providing evidence of validity in our sample (refer to Supplemental Table S1).

We also tested the fit of the configural, metric, and scalar invariance models for each CFA using the lavTestLRT function in the lavaan (Rosseel, 2012) to sequentially evaluate model fit and determine invariance type. All levels of invariance were satisfied for comparisons between cisgender LGBQ and cisgender straight biologists; however, metric and scalar invariance were not achieved for comparisons involving TGNC biologists. Although the chi-square difference test is standard for invariance testing, it is hypersensitive to large, unbalanced samples (such as the comparisons of TGNC individuals to both cis LGBQ and cis-straight participants), often flagging trivial fluctuations in the smaller group as statistically significant non-invariance (Chen, 2007). However, theoretically, the inability to achieve metric and scalar invariance may suggest that the scales used in our analyses are interpreted differently by TGNC biologists compared with their cisgender peers, including those who are cis LGBQ. While our content and face validity checks did not suggest any concerns, research indicates that gender identity and expression may impact workplace dynamics and social navigation more overtly than sexual orientation in professional STEM settings (Davidson, 2016; Ozturk and Tatli, 2016). As such, TGNC individuals may face a unique spectrum of social acceptance and structural barriers that shift the meaning of constructs such as "inclusion" or "belonging" (Fiani and Han, 2020).

Rather than converting analyses to factor scores and modifying the factor structure to force partial invariance, which may mask meaningful conceptual differences for TGNC biologists, we elected to report the observed means and standard deviations (Rohrer and Paulewicz, 2025). Given this study's exploratory nature, we use ordinary least squares (OLS) regressions descriptively to present between-group mean differences while still controlling for relevant covariates, establishing a preliminary baseline for future research (Berk, 2004; refer to *Analyses* section below for more details). This approach prioritizes descriptive visibility of disparities in TGNC scientists' lived experiences while acknowledging the unique psychological space they occupy within the field, a phenomenon we suspect our invariance testing is detecting. The CFA and invariance testing output can be found in Supplemental Tables S2–S8, and we caution interpretation of OLS regressions that report TGNC groups in the results; implications of this are discussed further in the *Limitations and future directions* section.

Recruitment and distribution

To compare LGBTQ+ biologists' experiences with those of straight, cisgender biologists, we recruited both LGBTQ+ and non-LGBTQ+ participants. Recruitment was initiated by the American Society of Cell Biology (ASCB) LGBTQ+ Committee. In summer 2023, ASCB leadership invited multiple societies to participate in helping to recruit biologists within their respective communities for this study. In addition to ASCB, four professional societies agreed to send out the study recruitment to their membership: Biophysical Society (BPS), Genetics Society of America (GSA), International Society for STEM Cell Research (ISSCR), and the Society for the Advancement of Biology Education Research (SABER). A snowball sampling approach was also used; the media teams from each community were also encouraged to use social media outlets to recruit any biologists interested in participating in the survey. Social media posts often encouraged biologists to invite other biologists to participate. The survey was open from June 1 to July 31 of 2023. Notably, data collection occurred after increased national dialogue on LGBTQ+ acceptance and discrimination stemming from state-level anti-LGBTQ+ legislation, such as the Florida Parental Rights in Education Act (House Bill 1557), commonly referred to as the "Don't Say Gay" law. However, data collection was completed before the 2024 US presidential election and subsequent federal policy changes limiting the rights of transgender individuals.

Analyses

We conducted all quantitative analyses in R version 4.5.2 (R. Core Team, 2025). We report the percent of participants who selected a particular response for single-item measures and summarize responses by reporting the means for multi-item scales. For all outcomes, we report overall descriptive statistics for LGBTQ+ participants and then disaggregate the responses between TGNC participants and cisgender LGBQ participants to respect the differences in experiences for biologists across the LGBTQ+ spectrum. For all regression analyses, the reference group is cisgender straight participants. All models were determined based on our research questions, and we controlled for variables known to affect the respective outcomes.

Although we did not employ QuantCrit (Gillborn *et al.*, 2023) or QuantQueer (Strunk, 2024) methodologies, these frameworks informed our approach to comparisons, treatment of identity categories, and emphasis on structural explanations for observed differences. We use straight and cisgender comparison groups not as benchmarks for normalcy, but as indicators of alignment with dominant norms that advantage some identities over others. Similarly, we engage in these comparisons not to assert a binary ontology of sexual and gender identity, but to examine how cisheteronormative organizational contexts differentially shape individuals' experiences. These comparisons enable conceptual alignment with the LGBTQ+ Climate in Physics study (Atherton *et al.*, 2016). Further, we did not conduct intersectional analyses because the sample sizes of some identity groups within LGBTQ+ subgroups were insufficient for robust analyses.

To what extent do the belonging, morale, and comfort of LGBTQ+ and non-LGBTQ+ biologists differ? To assess the extent to which LGBTQ+ individuals differ from non-LGBTQ+ individuals with regard to sense of belonging and feelings of morale across their professional societies, the biology community, and their workplaces, we calculated descriptive statistics and ran linear regressions using the stats package part of base R (R. Core Team, 2025). We ran one set of regressions for orientation (cis LGBQ biologists compared with cisgender straight biologists) and another for gender (comparing TGNC biologists to cisgender straight biologists).

Comparing the experiences of cis LGBQ biologists and cis straight biologists, our predictors included whether the participant reported an LGBQ orientation identity (0/1), binary gender (cisgender man/cisgender woman), race (Asian, Latine, white, or other), professional position (university faculty, university staff, student, or outside of academia), and region (Midwest United States, Northeast United States, Southeast United States, Southwest United States, Western United States, or outside of the United States). We omitted participants who did not identify as cisgender to focus this analysis on the differences between cisgender biologists with or without LGBQ orientation identities. Our reference groups were not reporting an LGBTQ+ identity, male, white, outside of academia, and outside of the United States.

In our models examining the experiences of participants with TGNC identities, we modeled each of the outcomes by gender (TGNC/cisgender straight), race (Asian, Latine, white, or other), professional position (university faculty, university staff, student, or outside of academia), and region (Midwest United States, Northeast United States, Southeast United States, Southwest United States, Western United States, or outside of the United States). Our reference groups were cisgender, white, outside of academia, and outside of the United States. For the models assessing professional society sense of belonging and feelings of morale, we also included professional society as a predictor. Of note, LGBQ identifying TGNC individuals are grouped as "TGNC" in these analyses, which contributes to the heterogeneity of experiences among TGNC biologists. Cisgender LGBQ participants were not included in these analyses because of their lived experiences; due to the intersection of their gender and orientation identities, we did not feel it was appropriate to group them with cis-straight individuals.

In presenting the results, we have anonymized professional society names and do not report on any significant differences between professional societies. If an individual was a member of multiple participating societies, they responded to these items for each society, and each entry was included in the model. Thus, we included a random effect of participant to account for multiple responses from participants who were members of multiple societies. To account for multiple hypothesis testing across these six regressions, we used Bonferroni corrections and used 0.008 (0.05/6) as the p-value threshold.

Similarly, to assess the differences in experiences between LGBTQ+ and non-LGBTQ+ individuals with regard to their workplace climate, we ran two sets of ordinal regressions using the ordinal package (Christensen, 2019). The two models had the same sets of predictors as described for the linear models above, with the outcome being participants' responses to the question regarding how comfortable they are with the climate in various professional contexts (campus, department, lab, as a student, or as an instructor). We again used Bonferroni corrections to account for multiple hypothesis testing, and 0.01 (0.05/5) was the p-value threshold.

We calculated the variance inflation factor (VIF) for both sets of predictors using the car package (Fox and Weisberg, 2018), which indicated minimal risk of multicollinearity among the predictors. Assumptions of linearity, homoscedasticity, and normality were checked and met for all linear regressions, and the proportional odds assumption was met for the ordinal regressions.

To what extent do LGBTQ+ individuals perceive their biology workplace to be inclusive/exclusive? We calculated the average score across the 12 positively worded items assessing LGBTQ+ inclusion and the average score across the eight negatively worded LGBTQ+ items assessing exclusion. We also calculated these average scores for cisgender LGBQ participants as well as TGNC participants. We assessed potential statistically significant differences between TGNC participants and cisgender LGBQ participants using linear regressions for the inclusion and exclusion scales while controlling for race, professional position, and region.

To what extent do LGBTQ+ biologists experience or witness exclusionary, intimidating, offensive, and/or hostile conduct at work and outside of work? We assessed the percentage of cis LGBQ and TGNC individuals who personally experienced exclusionary, intimidating, offensive, and/or hostile conduct at work, witnessed exclusionary, intimidating, offensive, and/or hostile conduct at work, and personally experienced exclusionary, intimidating, offensive, and/or hostile conduct outside of work. We used binary logistic regression analyses to determine whether TGNC participants and cis LGBQ participants differed in their experiences with exclusionary behaviors while controlling for race, professional position, and region in the regressions about the workplace and race and region in the regression of experiencing exclusionary behavior outside of work. In reporting the results of the logistic regressions, we use the odds ratio (OR) to describe the effect size. OR is calculated by exponentiating the β coefficient from the model output.

To what extent do LGBTQ+ biologists experience bias and discrimination in the biology community? We calculated cis LGBQ and TGNC participants' average scores on the scale measuring bias and discrimination against LGBTQ+ individuals in biology. We then assessed differences in perceived bias and discrimination against LGBTQ+ individuals in biology between cis LGBQ and TGNC participants using a linear regression while controlling for race, professional position, and region.

To what extent are LGBTQ+ individuals out in different biology environments? We calculated the percentages of all LGBTQ+ participants who were out in relation to eight circumstances. Percentages were calculated by dividing by the number of individuals who indicated the circumstance applied to them.

What recommendations do LGBTQ+ biologists have for creating more inclusive biology environments? To identify and describe common recommendations that participants had for making their professional societies and workplaces more inclusive for LGBTQ+ individuals, we analyzed participant responses to two open-ended questions eliciting recommendations from participants (Züll, 2016) using inductive qualitative content analysis (Krippendorff, 2018; Schreier, 2012; Vaismoradi *et al.*, 2013). Two researchers (C.A.B. and P.B.B.)

familiarized themselves with the data by reading through all open-ended responses to the survey questions: "What, if anything, could your respective professional society/societies do to make you feel more included as an LGBTQ+ individual?" and "What, if anything, could your workplace do to make you feel more included as an LGBTQ+ individual?" During the initial review, the researchers independently took analytic notes describing codes they identified emerging from the datasets. The two researchers came together to review their notes and identified that similar codes were emerging across the open-ended questions. Respondents echoed their own recommendations to create inclusive professional societies in their responses to the question that elicited recommendations to create an inclusive workplace. The coders met with additional members of the research team to discuss the emergent codes, and the group decided to combine all responses to the two questions and code them for recommendations to promote more inclusive biology environments.

Next, the two coders individually reviewed different randomly selected subsets of 10% of all responses and took analytic notes on themes that emerged from the text. Then, the researchers met to compare their codes and developed a preliminary codebook. After, one researcher (P.B.B.) tested the preliminary codebook on a randomly selected subset of 10% of the responses. Through this process, the researcher ensured that no new codes were present in the responses and that the codebook was complete. The two researchers then independently coded the same randomly selected subset of 15% of the responses using the codebook. Upon comparing their codes, they achieved excellent interrater reliability (Cohen's $K = 0.88$) as evidence of codebook validity. One researcher (P.B.B.) then coded all responses using the codebook. After the full dataset was coded, three researchers (P.B.B., C.A.B., and K.M.C.) met to organize the codes into categories (Schreier, 2012) of recommendations to create more inclusive biology environments.

RESULTS

Throughout the results, the term LGBTQ+ refers to any participant who indicated that they were a part of the LGBTQ+ community. The "cis LGBQ" group includes any participant who selected an orientation identity (e.g., lesbian, gay, bisexual, etc.) and reported that they are cisgender. The "TGNC" group includes individuals who did not select that they are cisgender, such as participants who selected agender, genderqueer, gender nonbinary, or transgender. Individuals within the TGNC group may also hold orientation identities. A summary of participant demographics is provided in Table 1.

We present descriptive statistics, as well as regression results to describe differences in means between groups of interest while still controlling for relevant covariates (Berk, 2004). It is important to remember that while all levels of invariance were satisfied for the comparisons between cisgender LGBQ and cisgender straight biologists, metric and scalar invariance were not achieved for any comparison involving TGNC biologists. While the chi-square difference test is hypersensitive to large, unbalanced samples (Chen, 2007), such as the comparisons of TGNC individuals to both cis LGBQ and cis-straight participants, the non-invariance may suggest that the underlying constructs may be interpreted differently by TGNC biologists compared with their cisgender peers, including those who are cis LGBQ.

TGNC biologists report lower belonging, morale, and comfort with climate across a variety of professional contexts compared with cis straight biologists.

Experiences of TGNC biologists. TGNC biologists reported lower sense of belonging and morale across professional contexts compared with cisgendered straight biologists: workplace (TGNC belonging: M = 6.7, SD = 2.4; morale: M = 6.4, SD = 2.5 vs. cis-straight belonging: M = 7.7, SD = 2.4; morale: M = 7.0, SD = 2.5), biology community (TGNC belonging: M = 6.4, SD = 2.2; morale: M = 6.8, SD = 2.1 vs. cis-straight belonging: M = 7.5, SD = 2.0; morale: M = 7.8, SD = 1.9), and professional societies (TGNC belonging: M = 6.2, SD = 1.9; morale: M = 7.1, SD = 1.8 vs. cis-straight belonging: M = 7.2, SD = 2.2; morale: M = 7.9, SD = 1.8). Controlling for race, professional position, and geographic location, the differences between TGNC and cis straight biologist belonging and morale were significant in the workplace (belonging: $\beta = -1.00$, $p < 0.0001$; morale: $\beta = -0.71$, $p = 0.004$), within the field of biology (belonging: $\beta = -1.05$, $p < 0.0001$; morale: $\beta = -1.02$, $p < 0.0001$), and in their professional societies (belonging: $\beta = -1.08$, $p = 0.0002$; morale: $\beta = -0.93$, $p = 0.0002$).

Most TGNC participants reported feeling comfortable or very comfortable on campus (56.9%), while 17.0% perceived a neutral campus climate, and 26.1% reported experiencing a very uncomfortable or uncomfortable campus climate. These trends were similar across other contexts. Most TGNC participants perceived a comfortable or very comfortable climate in their department (59.9%), lab (85.7%), and in the classroom as an instructor (75.3%). However, only 45.2% of TGNC participants perceived a comfortable or very comfortable experience in the classroom as a student. Conversely, the large majority of cis straight biologists reported feeling a comfortable or very comfortable climate on campus (70.8%), in their department (73.6%), in their lab (88.8%), in the classroom as an instructor (86.1%), and in the classroom as a student (65.6%). Supplemental Table S9 summarizes the disaggregated responses across all contexts. Overall, TGNC individuals perceived significantly less comfortable climates on campus ($\beta = -0.84$, $p < 0.0001$; Figure 1B), in their departments ($\beta = -0.58$, $p = 0.002$), and as students ($\beta = -1.28$, $p = 0.0003$) compared with cisgender straight participants.

Experiences of cis LGBQ biologists. Cisgender LGBQ biologists reported moderate sense of belonging and morale in the workplace (belonging: M = 7.1, SD = 2.3; morale: M = 6.7, SD = 2.3), biology community (belonging: M = 7.0, SD = 2.1; morale: M = 7.4, SD = 1.9), and professional societies (belonging: M = 6.6, SD = 2.2; morale: M = 7.3, SD = 1.8). All means for cis LGBQ biologists were lower than the means for cis straight biologists. However, controlling for gender, race, professional position, and geographic location, the only difference that was significant between cis LGBQ and cis straight biologists was lower feelings of morale in their professional societies ($\beta = -0.50$, $p = 0.004$).

The majority of cis LGBQ biologists perceived a comfortable or very comfortable environment on campus (66.6%),

TABLE 1. Participant demographic characteristics

Demographic		Percent (n)
Gender	Woman	47.0 (667)
	Man	41.3 (586)
	Non-binary or gender fluid	5.1 (72)
	Agender	0.9 (13)
	A gender that is not listed	0.8 (11)
	Decline to state	4.9 (70)
Race/ ethnicity	White	64.5 (915)
	Asian	11.5 (163)
	Hispanic, Latin*, or Spanish Origin	8.2 (116)
	More than one race/ethnicity	3.7 (53)
	Identity(ies) not listed	3.4 (48)
	Black or African American	2.6 (37)
	American Indian or Alaska Native	0.6 (8)
	Pacific Islander	0.1 (2)
	Decline to state	5.4 (77)
LGBTQ+	No	58.3 (827)
	Yes	34.2 (486)
	Decline to state	7.5 (106)
LGBTQ+ identity group	Cisgender LGBQ	22.1 (313)
	Trans, nonbinary, genderfluid, or genderqueer (TGNC)	10.8 (153)
	Decline to state	1.4 (20)
LGBTQ+ gender identity (can select >1)	Agender	1.3 (19)
	Gender-queer or gender non-binary	7.8 (111)
	Questioning	1.8 (26)
	Transgender man	1.3 (18)
	Transgender woman	0.7 (10)
	A gender not listed	1.3 (18)
	Decline to state	0.8 (11)
	Asexual or aromantic	2.7 (38)
LGBTQ+ orientation identity (can select >1)	Bisexual	9.7 137)
	Lesbian or gay	18.9 (268)
	Pansexual	3.5 (49)
	Queer	10.5 (149)
	Questioning	0.4 (6)
	An identity not listed	0.6 (9)
	Decline to state	0.2 (3)
	Outside of United States	22.1 (314)
Geographic location	Northeast United States	19.7 (280)
	Midwest United States	15.4 (219)
	West United States	14.7 (209)
	Southeast United States	12.8 (181)
	Southwest United States	5.6 (80)
	Decline to state	9.6 (136)
	University faculty	49.9 (708)
Professional position	University staff, lecturer, or postdoc	20.4 (290)
	University undergrad or grad student	15.3 (217)
	Position outside of academia (e.g., govt. or industry, nonprofit)	11.0 (156)
	Decline to state	3.4 (48)
	ASCB	416
Society (can select >1)	BPS	172
	GSA	353
	ISSCR	162
	SABER	176
	None	375

in their department (69.3%), in their lab (87.0%), in the classroom as an instructor (82.4%), and in the classroom as a student (63.9%; Supplemental Table S9). There were no significant differences in comfort with climate across contexts between cisgender LGBQ and straight cisgender biologists. Full results from both sets of regressions are available in Supplemental Tables S10 and S11. The comparison of TGNC, cisgender LGBQ, and cis straight biologists' sense of belonging and morale across contexts, as well as their comfort with different climates, is depicted in a forest plot in Figure 1.

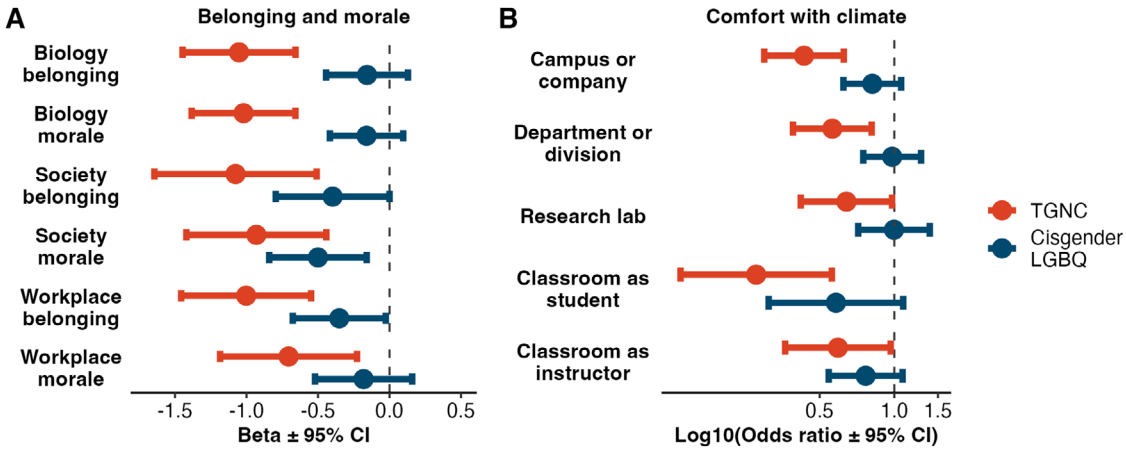

FIGURE 1. Forest plot of regression results from: (A) linear regressions of sense of belonging and feelings of morale in the biology community, professional societies, and workplace; and (B) ordinal regressions for comfort with climate across five common contexts. TGNC participants are represented in red and cisgender LGBQ participants in blue. Points and confidence intervals to the left of the vertical dashed line indicate that the represented group expressed a lower score on the respective outcome relative to the reference group (which, for all models, is cisgender straight biologists). Confidence intervals that do not cross the vertical dashed line are statistically significant.

Biology workplaces show mixed levels of LGBTQ+ inclusion and exclusion

Workplace inclusion. Of the individual items that comprise the inclusion factor (listed in Figure 2), over half the participants agreed with most statements indicating inclusive workplace environments. However, less than half of the participants agreed that "Non-LGBTQ+ employees are comfortable engaging in LGBTQ+ friendly humor with LGBTQ+ employees," "Employee LGBTQ+ identity does not seem to be an issue," and "Coworkers are as likely to ask nice, interested questions about LGBTQ+ relationships as they are about non-LGBTQ+ relationships." The 5-point scale measuring LGBTQ+ climate inclusion ranged from 1, strongly disagree, to 5, strongly agree, with higher scores indicating greater perceived inclusivity. The average score across all items for all LGBTQ+ participants was 3.5. Cisgender LGBQ participants had a mean score of 3.6, while TGNC participants' mean score was 3.4. When controlling for race, professional position, and geographic location, the difference between cis LGBQ and TGNC inclusion scores was significant ($\beta = -0.21, p = 0.005$).

Workplace exclusion. Of the individual items that comprise the exclusion factor (listed in Figure 2), over half of the participants disagreed with most statements, suggesting relatively inclusive workplace environments. However, less than half of participants disagreed that "Employees are expected not to act 'too gay'," and "Coworkers make comments that seem to indicate a lack of awareness of LGBTQ+ issues." The 5-point scale measuring LGBTQ+ climate inclusion ranged from 1, strongly disagree to 5, strongly agree, where lower scores indicate greater perceived inclusivity. The average score for all items among all LGBTQ+ participants was 2.5 out of 5, Cisgender LGBQ participants averaged 2.4, and TGNC participants reported an average of 2.6. When controlling for race, professional position, and geographic location, the difference between cis LGBQ and TGNC scores was not significant ($\beta = 0.16$, $p = 0.06$). The distribution of responses for LGBTQ+ inclusion and exclusion climates across all participants is shown in Figure 2, and full results from all regressions are in Supplemental Table S12.

Over 20% of all LGBTQ+ biologists experience exclusionary behavior at work

The contrast between moderate workplace inclusivity ratings and the actual experiences of LGBTQ+ participants is striking: 21.2% of all LGBTQ+ participants personally experienced exclusionary, intimidating, offensive, and/or hostile conduct due to their LGBTQ+ identity, which interfered with their ability to work or learn in their department or workplace within the previous year. Additionally, 38.5% observed or were made aware of such conduct directed toward others. Over 40% (43.6%) personally experienced exclusionary, intimidating, offensive, and/or hostile conduct outside of their department or workplace because of their LGBTQ+ identity within the previous year.

When examining the experiences of TGNC biologists specifically, we found that nearly 40% experienced exclusionary, intimidating, offensive, and/or hostile conduct at work and over 50% experienced it outside of work (Figure 3). When controlling for race, professional position, and geographic location, TGNC biologists were significantly more likely to report experiencing exclusionary, intimidating, offensive, and/or hostile conduct at work (OR = 3.73, $p < 0.0001$) and outside of work (OR = 2.67, $p < 0.0001$) compared with cis LGBQ biologists. Full regression results are available in Supplemental Table S13.

LGBTQ+ participants perceive moderate discrimination in biology

LGBTQ+ participants reported an average score of 3.2 out of 7 on the scale measuring discrimination against LGBTQ+ individuals in biology, where lower scores indicate

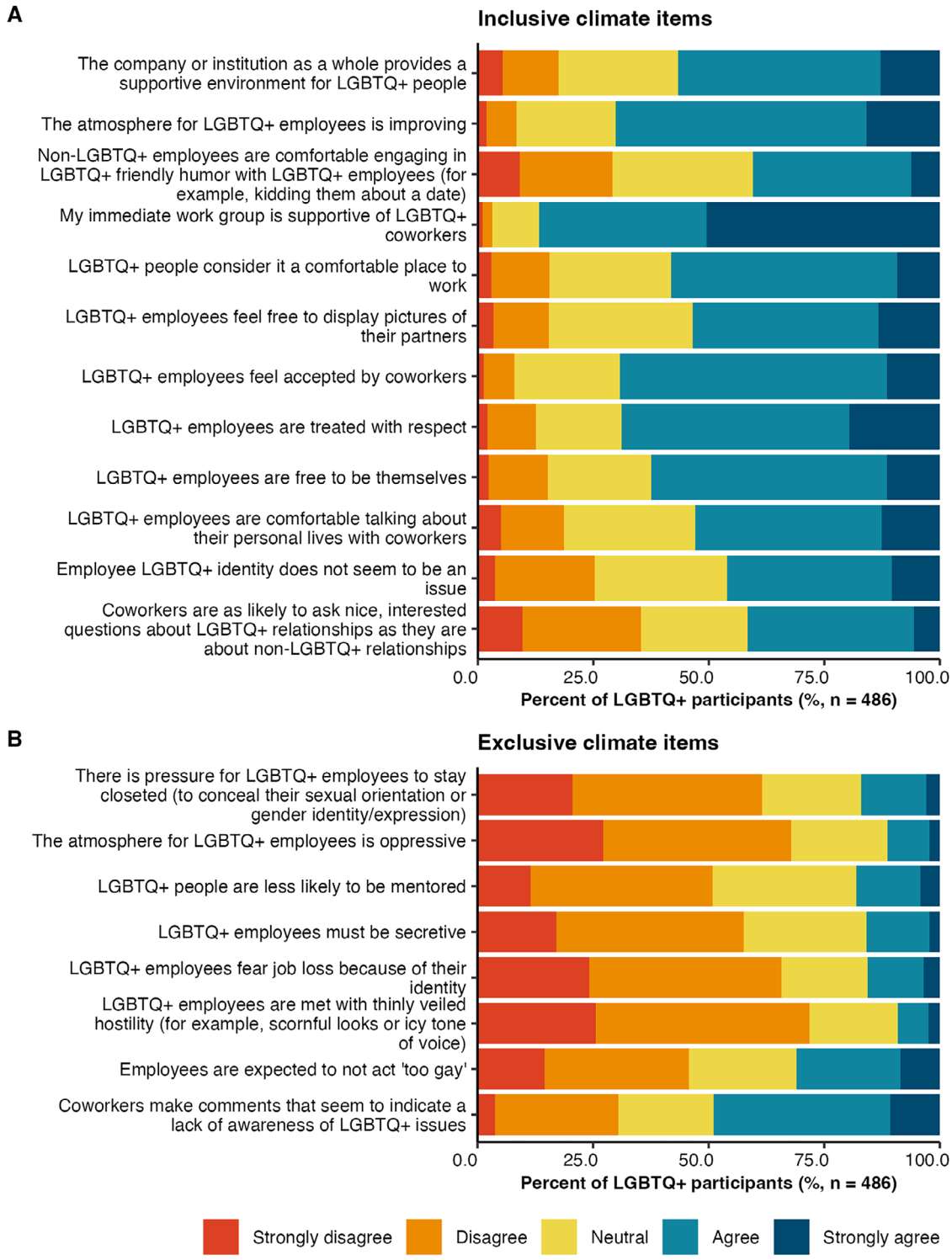

FIGURE 2. Distribution of responses from LGBTQ+ participants for the: (A) 12 positively worded LGBTQ+ inclusion items; and (B) eight negatively worded LGBTQ+ exclusion items assessing department/workplace climate.

greater discrimination in biology. When disaggregated by identity category, cisgender LGBQ participants scored an average of 3.5, while TGNC participants scored an average of 2.6. When controlling for race, professional position, and geographic location, TGNC participants perceived significantly more discrimination compared with cis LGBQ participants ($\beta = -0.88$, $p < 0.0001$). The distribution of responses across all LGBTQ+ participants is illustrated in Figure 4, and the full regression results are in Supplemental Table S14.

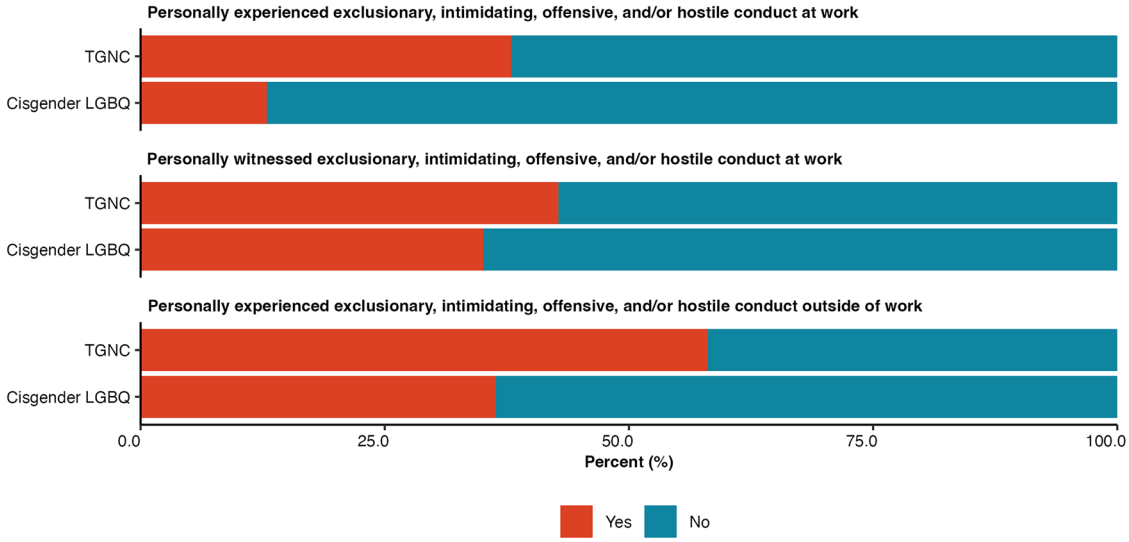

FIGURE 3. Distribution of responses from TGNC and cisgender LGBQ participants for whether they have (A) experienced exclusionary behavior at work, (B) witnessed exclusionary behavior at work, or (C) experienced exclusionary behavior outside of work.

LGBTQ+ biologists are somewhat open about their identities to coworkers, but few are out to undergraduates

Over half of all LGBTQ+ participants were out to most people across an array of professional and personal contexts. Within professional contexts, participants were most likely to be postdocs or graduate students in their research groups (67.7%). Of the participants teaching graduate courses, 55.1% were out to graduate students in the course they teach, and 16.2% were not. To coworkers or colleagues, 50.6% were out to all, while 5.4% were not out to any. LGBTQ+ biologists were least out to undergraduates in their courses; 23.7% were not out to any undergraduates (Figure 5A). Most LGBTQ+ biologists who were out to all coworkers or colleagues felt comfortable or very comfortable with their department climate (Figure 5B).

LGBTQ+ biologists recommend increased institutional and social support

Participants were asked how their workplaces or professional societies could be more inclusive of LGBTQ+ employees and members. In Table 2, we present categories that emerged from participant responses and provide two example quotes from participants; one that is specific to one's professional society and one that is specific to the workplace. Participants commonly recommended communicating institutional support by speaking out for LGBTQ+ individuals across both professional societies and workplaces. Specifically, participants called for addressing LGBTQ+ issues directly and avoiding an apolitical stance. As Participant 609 emphasized, if organizations do not take specific stances on policies that affect a particular group, "their silence is being read as support (for harmful

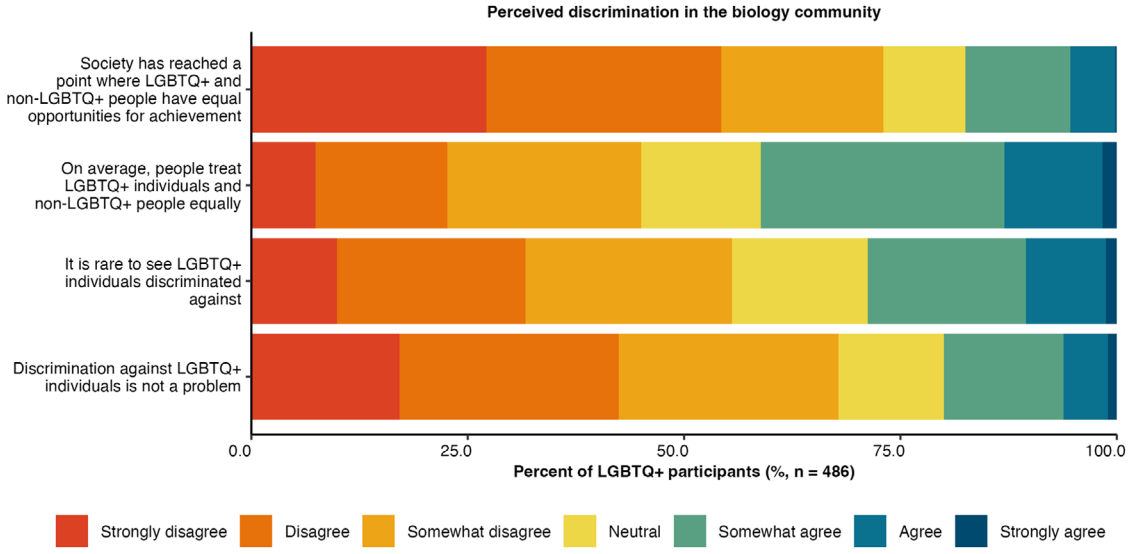

FIGURE 4. Distribution of responses from LGBTQ+ participants for the four indicated items assessing discrimination against LGBTQ+ individuals in biology.

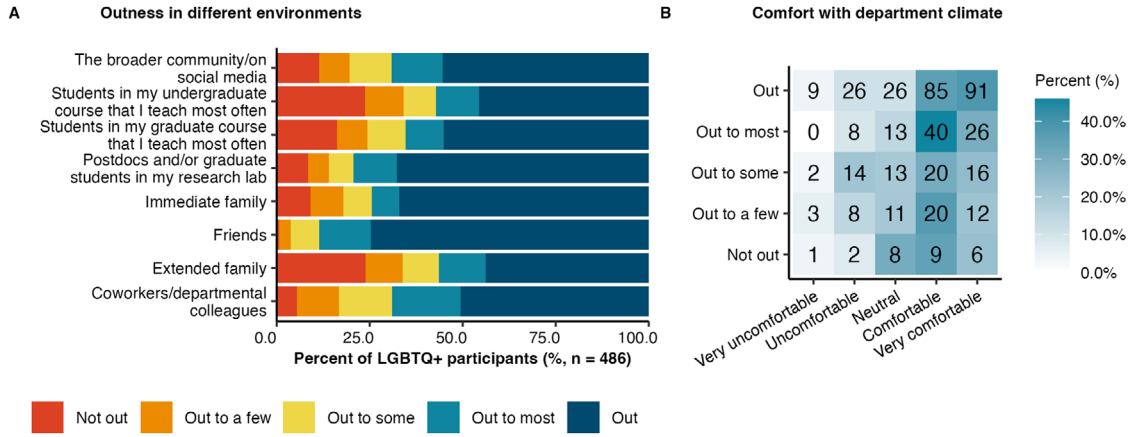

FIGURE 5. Distribution of responses from LGBTQ+ participants for (A) the degree to which they were out about their LGBTQ+ identities in various contexts, and (B) how outness to coworkers was related to comfort in the department/division. The numbers on the heatmap refer to the number of participants represented in that square (e.g., *n* = 9 participants reported being very uncomfortable in their department and were out). The shade of the square represents the percent of LGBTQ+ participants represented per degree of outness (i.e., each row).

policies)." LGBTQ+ participants also commonly recommended that professional societies and workplaces can facilitate social support in the form of LGBTQ+ meet-up groups, special interest groups, and LGBTQ+ mentoring, emphasizing the importance of having a network of LGBTQ+ scientists who can help one navigate professional environments. Relatedly, participants highlighted that both professional societies and workplaces would benefit from programming that promotes LGBTQ+ inclusion, such as workshops and trainings that inform community members about LGBTQ+ challenges (such as bias and exclusion of queer people as described by Participant 1321), problematic conduct, and how to create an inclusive environment (including being cognizant of language, as emphasized by Participant 2016). Further, LGBTQ+ study participants described that both societies and workplaces can make an effort to increase visibility or promote LGBTQ+ representation. Participants provided suggestions such as "celebrating LGBTQ+ visibility (Participant 1567)" and "provide more visibility of the LGBTQ+ research community (Participant 621)." We also noted that participants often emphasized the importance of dedicating attention to transgender and gender nonbinary issues. Specific recommendations suggested "Better use of pronouns, preferred names, gender inclusive restrooms (…) gender and surname options for forms/records (Participant 1650)." Additional recommendations are described in Table 2.

DISCUSSION

In this study, using data collected in 2023, we compared the experiences of LGBTQ+ biologists to those of straight and cisgender biologists, not as benchmarks for normalcy, but as indicators of alignment with dominant cisheteronormative norms. We also acknowledge that experiences of people with identities across the LGBTQ+ spectrum are not homogenous and that TGNC individuals experience more severe harassment, discrimination, and violence than their cis LGBQ peers (Coburn *et al.*, 2025; Devís-Devís *et al.*, 2022; Sears *et al.*, 2021). Accordingly, to acknowledge these potentially important differences in lived experiences, we analyzed the data by disaggregating cis LGBQ and TGNC biologists' experiences.

Our study revealed differences between the experiences of cis LGBQ and TGNC biologists across biology culture (e.g., perceptions of climate), interpersonal experiences (e.g., experienced discrimination), and individual experiences (e.g., feelings of belonging), all of which shape LGBTQ+ experiences in biology learning and working environments (Marosi *et al.*, 2025). These results highlight the need to disaggregate identities when examining the experiences of LGBTQ+ scientists. Specifically, while cis LGBQ and non-LGBTQ+ biologists reported similar belonging and morale in the workplace and biology community, and similar comfort with the climate across a variety of professional contexts, TGNC biologists consistently reported substantially lower belonging, morale, and climate than their straight and cis peers. This echoes findings from the 2016 APS LGBTQ+ climate in physics survey (Atherton *et al.*, 2016), showing that, compared with all LGBTQ+ physicists, a greater percentage of gender nonconforming individuals described their workplace as uncomfortable or very uncomfortable.

Compared with data from 2021 showing that LGBTQ+ scientists are more likely to report career limitations and professional devaluation than non-LGBTQ+ scientists (Cech and Waidzunas, 2021), the increased public acceptance of orientation identities (GLAAD, 2023) combined with specific recommendations and efforts to increase inclusion among LGBTQ+ biologists (Alexander *et al.*, 2023, 2024; Cooper *et al.*, 2020; Harris *et al.*, 2024) may have partially contributed to the relatively promising belonging, comfort, and morale levels among LGBQ biologists; although substantial non-acceptance of LGB individuals persists in the United States (Minkin *et al.*, 2025).

Our data reveal that efforts to increase LGBTQ+ inclusion have fallen short of closing belonging, morale, and comfort gaps for TGNC biologists. These gaps are unsurprising considering the overwhelming anti-TGNC legislation in the United States before this study (Mapping Attacks on LGBTQ Rights in U.S. State Legislatures in 2023, 2023) and the lack of studies

TABLE 2. Participant-generated recommendations, frequencies, and example quotes for how to create more inclusive professional societies and workplaces for LGBTQ+ individuals

Code	Description	Society % (n)	Example quote - professional society	Workplace % (n)	Example quote - workplace
Communicate institutional support	The workplace or society could speak out in support of LGBTQ+ individuals, address LGBTQ+ issues head-on, use inclusive and careful language, and avoid an apolitical stance.	25.8 (65)	Participant 1444: Speak out in favor of LGBTQ+ people. Give a platform to LGBTQ+ members.	23.0 (61)	Participant 609: Take a stance against the state policies. Stop being quiet about these laws affecting healthcare for LGBTQ+ individuals and women. Their silence is being read as support.
Social support/ mentoring	The workplace or society could increase social support and mentoring for LGBTQ+ individuals by having meet-up groups, affinity groups, and programming specifically for LGBTQ+ people.	23.8 (60)	Participant 1321: Organize queer events (meet-ups, happy hours, symposia) at conferences and encourage attendance by all.	10.6 (28)	Participant 1251: The thing I would most appreciate is access to identity-specific mentorship [and specifically] professional guidance from more senior LGBTQ+ researchers about how to navigate life as an out scientist.
Increase visibility/ representation	The workplace or society could increase LGBTQ+ visibility and representation through pride flags, celebrating pride, and having LGBTQ+ individuals in leadership positions.	16.7 (42)	Participant 1567: I think promoting and celebrating LGBTQI+ visibility. I feel a real problem is simply a lack of role models because by and large LGBTQI+ people are not publicly visible.	16.2 (43)	Participant 621: Provide more visibility of LGBTQ+ research community.
Programming	The workplace or society could support and train others on how to be inclusive to LGBTQ+ individuals through programming, sensitivity training, and talks by LGBTQ+ individuals.	12.7 (32)	Participant 2016: Conferences could host workshop and conversations about how to be more inclusive in our research labs, teaching roles (especially with language!), and departmental service positions.	16.2 (43)	Participant 1321: Implement trainings about bias, gender identity, workplace conduct, historical bias, and exclusion of queer people in science.
Trans/nonbinary awareness	The workplace or society could pay attention to issues affecting transgender and genderqueer individuals, including making gender-neutral bathrooms available and ensuring the correct pronouns and names are used.	14.3 (36)	Participant 1650: Better use of pronouns and preferred names, gender inclusive restrooms at conference, gender and surname options for forms / records.	13.6 (36)	Participant 1639: I wish that pronouns were more respected. No one really seems to care and I'm constantly misgendered.
Institutional action	The workplace or society could take institutional action to change the cisheteronormative policies including family leave, hiring processes, insurance coverage, spousal hires, and pay equity.	3.6 (9)	Participant 1174: Start supporting and asking for policies that ensure the health and security of LGTBIQ+ community.	11.3 (30)	Participant 1401: Provide expansive health care benefits for LGBTQ+ employees (…). Provide explicit leave for LGBTQ+ people when undergoing healthcare procedures. Provide financial support for fertility services, adoption, and other family-related expenses.

(*Continues*)

TABLE 2. Continued

Code	Description	Society % (n)	Example quote - professional society	Workplace % (n)	Example quote - workplace
Accountability for individuals	The workplace or society could curb discrimination and homophobia by improving reporting mechanisms and having consequences for harassment.	4.4 (11)	Participant 1590: Zero tolerance policies. I'm tired of people with harmful views being allowed to continue working or not receive serious repercussions for their words or actions. It makes me feel not seen and invalidates my experiences.	7.2 (19)	Participant 1212: Sanctions need to be applied when individuals misbehave due to someone's identity/orientation.
Financial support	The workplace or society could provide financial support for LGBTQ+ individuals via grants, donations, funding, fellowships, or scholarships.	6.0 (15)	Participant 618: LGBTQ+ students need funding and resources to find success in their respective societies. We need funding to attend events and meetings.	5.3 (14)	Participant 1314: Offer grants, fellowships and funding schemes that acknowledge the barriers in sustaining an academic career as a LGBTQI+ individual, and work towards retaining them within the workplace.
Consider regional politics	The workplace or society could avoid hosting events in places with anti-LGBTQ+ legislation or could consider local politics when making the decision of where to hold events.	8.3 (21)	Participant 1225: Consider the locations of annual meetings/conferences and the impact of state and local policies on LGBTQIA+ attendees and their ability to feel safe.	0.0 (0)	*n/a*
Intersectional diversity, equity, and inclusion measures	The workplace or society could engage in diversity, equity, and inclusion initiatives broadly, including hiring a more diverse group.	7.1 (18)	Participant 1299: Continue to put all EDI [equity, diversity, and inclusion] issues in the forefront, be vocal about allyship and support.	3.4 (9)	Participant 407: Put more effort towards diversity and inclusion rather than leaving it up to a committee which faces lots of restrictions, and make sure that LGBTQ+ people are a part of the conversation on how this happens.
Collect data	Funding institutions (including their workplace or society) could collect data about LGBTQ+ identities.	3.2 (8)	Participant 1251: I think it is critical to continue to do these types of surveys, and to collect overall demographic information about LGBTQ+ scientists in these societies. We are so often overlooked in surveys and censuses, and this makes it very difficult to quantify the challenges we face and to design strategies to address them.	0.8 (2)	Participant 1306: Collect data and work to understand how LGBTQ+ faculty, staff, and students are doing in programs and work.
Confidentiality	The society or workplace could take care to ensure confidentiality when handling personal data, communicate why it is being collected, and not disclose the LGBTQ+ identities of members to others.	1.2 (3)	Participant 312: [My professional society] revealed people's LGBTQ identity on [a] form to [others], which inadvertently outed people. More attention needs to be placed on the confidentiality of this identity.	0.4 (1)	Participant 1281: Don't spread that information [individuals' LGBTQ+ identity] to others, it is the individual's business to share, no one else's.

Percentages are out of the total responses for the given prompt, $n = 252$ for recommendations for professional societies and $n = 265$ for recommendations for workplaces.

centering TGNC participants (Davis and Yeung, 2022). Since this study was conducted, there have been increasing attacks on gender-affirming care and transgender health care (*Attacks on Gender-Affirming and Transgender Health Care | ACP Online*, 2025) and consistent reporting of non-acceptance of trans and non-binary individuals in the United States (Minkin *et al.*, 2025), suggesting that these gaps have likely widened further. However, recent studies are beginning to explicitly examine the experiences of TGNC people in biology, particularly undergraduates (A. A. Casper, Rebolledo *et al.*, 2022), and there is increased documentation of efforts to reform biology curriculum to be more inclusive of students with queer genders (A. M. A. Casper *et al.*, 2025; Driessen *et al.*, 2024; D. Jackson *et al.*, 2024). While these efforts may not impact the experiences of practicing scientists to the same extent that they may impact scientists in training, future evaluations are needed to assess whether they are having a positive impact on the inclusion of rising TGNC biologists.

The current study found that LGBTQ+ biologists are relatively open about their identities across contexts, and much more likely to be out than in previous years. Over half of LGBTQ+ biologists were out to all their colleagues, compared with only a third of a national sample of 60 LGBTQ+ biologists in a 2019 study (Cooper *et al.*, 2019). Additionally, in the 2016 APS climate in physics survey (Atherton *et al.*, 2016), 53% of individuals who were very comfortable in their department were out to everyone, compared with 60% of biologists in the current study. While participants in the current study were least open about their identity in their undergraduate courses, with 24% not being out to any students, this is a vast improvement from the 65% of biologists who were not out to any undergraduates in 2019 (Cooper *et al.*, 2019). The suggested increase in LGBTQ+ biologists coming out to undergraduates is encouraging, given recent research highlighting that most students in biology courses benefit from LGBTQ+ visibility and representation among scientists, regardless of whether they hold an LGBTQ+ identity (Busch, Bhanderi *et al.*, 2024; Busch *et al.*, 2022). While this progress is promising, the fact that nearly a quarter of LGBTQ+ biologists are not out to any undergraduates indicates ongoing challenges.

Our data also suggest that there is still room for improvement regarding creating more inclusive biology workplaces. While it is encouraging that more than half of LGBTQ+ biologists agreed with 75% of the statements describing inclusive aspects of the workplace, more than half of physicists surveyed agreed with 100% of the same statements in 2015 (Atherton *et al.*, 2016). This raises the question of whether physics disciplines have historically been more welcoming of LGBTQ+ scientists or whether climates in science have simply not improved over time. Importantly, in the current study, over 20% of all LGBTQ+ participants and nearly 40% of TGNC participants experience intimidating, offensive, and/or hostile behavior at work due to their identity. Unfortunately, these numbers were relatively similar to those reported nearly a decade ago in the LGBT+ climate in physics survey, in which 22% of cis LGBQ physicists and nearly 50% of trans physicists experienced exclusionary behavior at work. Together, these findings underscore the immediate need for biology workplaces and professional communities to evaluate their internal climates and work toward meaningful structural and cultural changes to better support LGBTQ+ scientists.

Participants provided helpful recommendations to promote inclusive professional societies and workplaces, targeting improvement of both the biology culture and interpersonal interactions (Marosi *et al.*, 2025). The most common recommendation, to communicate institutional support by speaking out for LGBTQ+ individuals, emphasizes improving STEM climates by addressing LGBTQ+ issues directly and avoiding an apolitical stance, which underscores the ostensibly apolitical culture of science (Cech, 2013; Cech and Waidzunas, 2021; Hughes and Kothari, 2023; Mattheis *et al.*, 2019) and aligns with research showing that when companies take a public stance on socio-political issues that align with employees' ideologies, it can improve satisfaction (Mkrtchyan *et al.*, 2024). Relatedly, participants highlighted the importance of integrating programming to support and train people in the workplace about how to be inclusive of LGBTQ+ employees. Employers interested in adopting these recommendations should explore resources, such as the Safe Zone Project (thesafezoneproject.com; The Safe Zone Project, 2019), which provides curricula, activities and other resources for LGBTQ+ education sessions, and the Human Rights Campaign Establishing an Allies/Safe Zone Program (hrc.org/resources/establishing-an-allies-safe-zone-program; *Establishing an Allies/Safe Zone Program*, n.d.), which provides a step-by-step guide to establishing an LGBTQ+ ally program to make the culture of a workplace more inclusive of LGBTQ+ people. Study participants also highlighted the importance of positive interpersonal relationships, suggesting that societies and workplaces facilitate social support and mentoring. While research shows that LGBTQ+ specific mentors have had positive impacts on undergraduates and medical students (Beanlands *et al.*, 2020; Sarna *et al.*, 2021), more research is needed to identify the benefits of these relationships among professional scientists. Finally, participants echoed a common theme in our findings, the lack of inclusion for TGNC biologists, by acknowledging the need to specifically support transgender and gender nonbinary scientists. Notably, their specific recommendations, including paying attention to pronouns, providing gender-inclusive bathrooms, and allowing for institutions to utilize the name someone uses, have been repeatedly suggested (Cooper *et al.*, 2020; Gregor *et al.*, 2023; Huffman *et al.*, 2021), emphasizing that these efforts are either not being implemented, are insufficient to promote an inclusive STEM climate, or both.

Limitations and future directions

First and foremost, the data for this study were collected in the summer of 2023. Since January 2025, there has been a substantial increase in anti-LGBTQ+ and especially anti-trans rhetoric and policies in the United States. This constantly changing political landscape may affect LGBTQ+ biologists' perceptions of belonging and climate, as well as their experiences with harassment, emphasizing the importance of the continued assessment of LGBTQ+ biologists' perceptions and experiences. Future surveys will allow us to compare the current experiences of LGBTQ+ biologists to those reported in this study.

This study is susceptible to volunteer bias; the survey participants, particularly the LGBTQ+ respondents, may be

inherently more comfortable with their LGBTQ+ identities or feel safer filling out surveys than LGBTQ+ biologists who chose not to participate (Wiederman, 1999). Further, our question assessing LGBTQ+ identity first asked individuals whether they identified as a member of the LGBTQ+ community, which was interpreted as intended by the 22 LGBTQ+ biologists who reviewed the demographic question. However, it is possible that some biologists may have interpreted this question to mean belonging to a community of LGBTQ+ people and answered "no," rather than answering "yes" (they identify as LGBTQ+). As such, we may be overestimating the belonging and morale of LGBTQ+ biologists. Additionally, because participants were primarily recruited through professional society listservs, this limits the engagement of biologists who are not members of professional societies. Further, the professional societies originally invited to help with recruitment for this study do not comprehensively represent all sub-fields in biology.

The findings of this study point to critical areas of future research, particularly examining the intersectional experiences of individuals who hold specific identities within the LGBTQ+ umbrella and those who hold other marginalized identities. Great variation still exists among individuals within the subgroups of the LGBTQ+ community (Fiani and Han, 2020; Hall *et al.*, 2021).

Our findings also illuminate a methodological frontier in LGBTQ+ STEM research. The failure to achieve metric and scalar invariance for TGNC participants, while achieving it for cisgender LGBQ participants, suggests that standard "belonging" and "morale" metrics may carry different conceptual weights for TGNC biologists. As gender identity often necessitates more frequent and overt navigation of workplace dynamics and social acceptance than sexual orientation (Davidson, 2016; Ozturk and Tatli, 2016), the very nature of "professional inclusion" may be a distinct construct for TGNC individuals, which conveys two important possibilities. First, there is likely a confounding variable, such as visibility of TGNC status, which may be the true cause of the fundamental differences we detected between TGNC response patterns and cis-straight and cis LGBQ response patterns in our invariance testing. More quantitative research differentiating between the experiences of TGNC scientists, cis LGBQ scientists, and cis straight scientists is needed to identify these influential factors. Second, our invariance testing communicates that it is worth developing additional tools to better understand TGNC populations in future research. While this study intended to build upon previous research, we hope to also encourage scholars to engage in scale development informed by the LGBTQ+ community, and identify whether existing instruments for related projects are measuring what they intend to, or if they fail to adequately capture unique stressors (e.g., gender policing, misused pronouns) which are known to alter how TGNC scientists perceive their environment (McLemore, 2018; Schilt and Connell, 2007). By treating the lack of measurement invariance not as a statistical error, but as a reflection of unique social experiences, future research can better account for the "measurement gap" between cisgender and TGNC experiences in the sciences.

Conclusions

In the largest survey to date of LGBTQ+ biologists, with data collected in 2023, we examined how their sense of belonging, morale, and perception of climate in the biology workplace and professional societies compare to that of their straight and cis peers. Trans and gender non-conforming (TGNC) biologists reported lower belonging and morale within the workplace, professional societies, and the biology community compared with cis straight biologists. They also reported being less comfortable with the climate of various professional biology environments. While LGBTQ+ biologists report that their workplaces are moderately inclusive, over 20% of all LGBTQ+ biologists and nearly 40% of TGNC biologists experience exclusionary behavior at work. The research provides foundational insight into the current challenges experienced by cis LGBQ and TGNC biologists and invites the biology community to embrace the participant-generated recommendations in hopes that we can move toward a future where all biologists, regardless of their sexual orientation or gender identity, can thrive and contribute fully to the scientific enterprise.

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