RE-ENVISIONING UNDERGRADUATE RESEARCH EXPERIENCES

TO INCREASE DIVERSITY, EQUITY, AND INCLUSION, AND HARNESS THE POWER OF DIVERSITY IN OCEAN SCIENCES

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ABSTRACT. Diversity in ocean sciences lags far behind US demographics. A substantial body of research highlights barriers that limit the participation and success of students from underrepresented minoritized (URM) and other marginalized groups in STEM disciplines, and a wealth of studies highlight successful interventions that improve the persistence of these groups in STEM higher education. Despite this knowledge, over the past four decades, ocean sciences has made limited progress in growing diversity within its workforce, suggesting new strategies are needed. Undergraduate research experiences are a pivotal pathway toward graduate education and future careers in ocean sciences, but they are plagued by many issues that limit the participation and success of persons from URM and other marginalized backgrounds. Here we summarize obstacles that limit participation of diverse populations in ocean sciences and highlight successful strategies for overcoming these obstacles. By re-envisioning how we approach undergraduate research experiences and bringing intentionality to the recruitment of students and the training environments that they experience, we can more effectively grow diversity in ocean sciences and unleash the power of diversity to address the pressing local and global problems facing marine ecosystems.

INTRODUCTION

Science has a well-documented diversity problem (Schultz et al., 2011; Bernard and Cooperdock, 2018; Miriti, 2020). Nearly 35% of the US population (https://www.census.gov/quickfacts/) comes from underrepresented minoritized (URM) populations (Black, African American, Hispanic/Latina/o/x, Indigenous/Native American, Alaska Native, Native Hawaiian, Pacific Islanders), yet comprises only 16% of the STEM workforce that requires at least a bachelor's degree (NCSES, 2023). Although the drivers of this pattern are multifaceted and complex, a substantial literature highlights barriers faced by URM STEM students in higher education that result in their leaving STEM majors at a rate twice that of well-represented students (Crisp et al., 2009; NASEM, 2011). Although frequently described as a "leaky pipeline" (Schultz et al., 2011), a recent, more appropriate metaphor is the "hostile obstacle course" (Berhe et al., 2022), where URM students face challenges that are less common for students from ethnicities well-represented in STEM. For example, URM students are more likely to be first-generation college students who struggle in the transition from high school to college (Choy et al., 2000; Chavira et al., 2016) and face an unwelcoming and discouraging academic culture and climate (Beasley and Fischer, 2012). These negative experiences can be particularly profound in introductory college math and science courses, where students find difficulty because of insufficient high school preparation and the disproportionate negative (and incorrect) perceptions of their interest and ability in STEM, leading to higher attrition rates (Strenta et al., 1994; Elliott et al., 1996; Kokkelenberg and Sinha, 2010; Whalen and Shelley, 2010; Estrada et al., 2016).

The substantial growth in the diversity of students earning STEM degrees highlights the progress being made broadly in STEM (NCES, 2023). However, there has been a notable lack of growth in diversity in the geosciences, including ocean sciences (Bernard and Cooperdock, 2018; Garza, 2021). The failure of ocean sciences to diversify can be partially attributed to the well-documented obstacles noted above that face URM students at the collegiate level and URM groups throughout STEM more broadly (Barber et al., 2020; Berhe et al., 2022). While it is critical to address these systemic issues, it is also important to address the unique challenges posed in ocean sciences. For example, Abdel-Rahim et al. (2023, in this issue) outline the compounding impacts of oppressive experiences faced by those

with intersecting marginalized identities in ocean sciences, from individual, everyday challenges, to larger, deeply ingrained systemic issues, and how this legacy of abuse and exclusion results in the historic, persistent, and current lack of representation of groups with identities outside of the dominant culture. Similarly, authors in this special issue highlight the financial and physical hurdles that differentially impact students of color engaged in scientific dive training (Barber et al., 2023; Kamer, et al., 2023, both in this issue). Isma et al. (2023, in this issue) describe the discrimination and financial burdens faced by Black women, including racialized wealth disparities and decreased access to merit-based financial assistance. Osborne et al. (2023, in this issue) report pervasive sexual assault and sexual harassment, particularly in academic and fieldwork settings such as ships and remote field stations. URM populations also face disproportionate harassment in environmental initiatives and outdoor spaces (Demery and Pipkin, 2021; Pedra Nobre et al., 2023, in this issue), and barriers associated with physical differences and with neurodiversity are especially compounded in field locations, including onboard ships (Bower et al., 2023; Wilson, et al., 2023, both in this issue). For individuals who hold multiple marginalized identities, the risks and impacts are compounded.

Lack of diversity in ocean sciences isn't simply an equity issue—diversity increases the quality and impact of the scientific enterprise (Nielsen et al., 2018; Swartz et al., 2019; Hofstra et al., 2020; Yang et al., 2022), and a diversified ocean sciences workforce can help address the most pressing issues of twenty-first century ocean science (Harris et al., 2022). Efforts that have been initiated to improve diversity in STEM focus on making undergraduate education more inclusive through re-envisioning how we teach our students (e.g., AAAS, 2009; PCAST, 2012). Programs like the Meyerhoff Scholars Program (Maton et al., 2016), Biology Scholars Program (Aldana et al., 2021), and the Program for Excellence in Education and Research in the Sciences (Toven-Lindsey et al., 2015; Sellami et al., 2021) provide academic support for URM students to develop the skills to succeed in STEM and create supportive communities essential to student success. However, a critical but frequently overlooked pathway for diversifying STEM fields is undergraduate research experiences.

In many fields, structured field- or lab-based undergraduate research experiences are an integral part of academic preparation (Orion, 1994; Orion and Hofstein, 1994; Orion et al., 1997; Plymate et al., 2005); within the geosciences, participating in undergraduate research is viewed as critical for success and aids in development of an individual's science identity (Cooper et al., 2019). Not only are undergraduate research experiences pivotal to students pursuing STEM careers (Laursen et al., 2010), they can be life-changing experiences that are particularly impactful for URM students (Jones et al., 2010; Pender et al., 2010; Schultz et al., 2011). Yet, there are significant barriers limiting URM student participation in undergraduate research, ranging from time and financial constraints to lack of diverse faculty role models (Pierszalowski et al., 2021). Not being part of the dominant culture of STEM, many URM students lack the experiential, cultural, and political capital to access these transformative experiences and are disparately impacted by traditional views of success and potential. By actively addressing barriers to participation of underrepresented and otherwise marginalized students in undergraduate research, ocean sciences can catalyze a more rapid increase in the diversity of the ocean science workforce.

Summer research experiences such as the National Science Foundation-funded Research Experiences for Undergraduates (REU) program and other similarly structured programs offered by many research-intensive universities and institutions can have profound impacts on URM students and increase their interest in pursuing graduate school (Pender et al., 2010; Carpi et al., 2017). However, if programs are not intentional in how they are structured and administered, rather than introducing new images of science that invite participation and inclusion, they can reinforce flawed images and/or result in negative experiences (Linn, 2015) that may ultimately discourage URM students and other marginalized groups from continuing in STEM fields.

Holistic processes and procedures, shifts in mindsets, and what qualities/characteristics are valued are essential when considering the potential of diverse candidates rather than determining whether they fit into traditional models with known barriers. Here we draw on the literature and our collective experience to outline barriers to participation in ocean sciences and highlight effective strategies for creating research experiences that help undergraduates from underrepresented and marginalized backgrounds overcome the hostile obstacle course that often limits their success (summarized in Table 1).

RECRUITMENT

Understand and Mitigate Sources of Bias

A significant barrier to diversifying pathways to ocean science careers is that individuals from dominant cultures and ethnicities in STEM often fail to see the lack of progress in diversity and/or blame lack of diversity on "pipeline" problems (Bateman et al., 2021) that are out of their control (e.g., deficiencies in K–12 education). Compounding this issue is the "meritocracy myth" that suggests all students who work hard have an equal opportunity to succeed (Rodriguez, 1998) while studies show a different reality. Variables extrinsic to student ability, potential, and work ethic, such as family income (Whalen and Shelley, 2010) and parental education (Suárez et al., 2021), are significant predictors of student success in STEM majors. Moreover, not only are university STEM faculty 25 times more likely to have parents with PhDs

(Morgan et al., 2022), highlighting socioeconomic biases limiting diversity, there is a strong bias in academia to hire from a limited number of "elite" institutions. For example, one in eight tenure track professors received their degree from one of five research-intensive universities, and 80% of tenure track faculty are produced by only 20% of PhD granting institutions (Wapman et al., 2022). Institutional biases are compounded by gender biases. For example, faculty at US universities display significant biases in providing training opportunities, with faculty being more likely to respond to emails from prospective PhD students if the sender appears to be a White male rather than a woman or URM person (Milkman et al., 2015). Similarly, employers are less likely to consider job applicants with "Black sounding" names (Kline et al., 2022). Understanding how these biases limit the access of URM groups to training opportunities and careers in marine science (faculty or otherwise) provides a roadmap for how leaders of undergraduate research programs can contribute to the diversification of their fields through intentional approaches to recruiting faculty, staff, and student participants. In the following text, we present many strategies that practitioners of undergraduate research programs can use to diversify their participants.

Broaden Recruitment Strategies

Recruitment efforts should actively engage faculty and students at Minority Serving Institutions (MSIs) such as Historically Black Colleges and Universities (HBCUs), Hispanic Serving Institutions (HSIs), Pacific Islander Serving

TABLE 1. Summary of practices that are effective for building diversity in undergraduate research experience programs, with particular focus on diversifying program staff and student cohorts, building equity in processes and procedures, and improving the culture of inclusion and safety for all. Considerations for training and support of staff and students is included, as is the need for relationship building, intentionality, and sustained commitment to improve retention of diverse scholars in STEM beyond summer programming. These examples represent a synthesis of the educational literature and the collective experiences of the authors, and are drawn from programs on the leading edge of diversifying ocean sciences. Additional insights can be found in the GEO REU Handbook, developed by Valerie Sloan and Rebecca Hacker, that remains a valuable resource for development of diverse, equitable, inclusive summer research programs (Sloan and Hacker, 2020).

PROGRAM COMPONENTS	STRUCTURAL CONSIDERATIONS	RECOMMENDATIONS
Recruitment	Active and Targeted Recruitment	Recruitment must be active, intentional, and relational for students as well as faculty and staff. Recruitment efforts must include Minority Serving Institutions such as Historically Black Colleges and Universities, Hispanic Serving Institutions, Pacific Islander Serving Institutions, Native Alaskan Serving Institutions, Tribal Colleges, and two-year institutions like community colleges, and should engage networks and communities outside of dominant culture spaces.
	Communication and Marketing	Recruitment materials and communications should be framed using inclusive language and with cultural relevance, and must reflect diversity, equity, inclusion, accessibility, and justice (DEIAJ) values and commitment.
Financial Assistance	Program Funding	Program participation should be fully funded. All participants should receive equitable funding for full participation, including cost of travel, housing, room/board, stipends, conference attendance, and local transportation.
	Stipend Timing	Provide students with a full or partial stipend at or before the start of the program to allow those without resources to pay for food and local transportation, and to cover any additional costs.
	Clothing and Gear	Build equity into considerations of dress codes, field gear, footwear, etc. Because participants come from variable financial circumstances, programs should provide students with specialized clothing/equipment or funding to purchase these items.
Preparation	Bridging Preparation Gaps	Provide guidance on how to develop a competitive application package through webinars, social media, posting of videos, etc. Reach out to students who start, but don't complete, applications for one-on-one guidance.
Rubrics of Measurement	Application Components	Application components should be designed to consider and value characteristics of individuals in new and different ways, to mitigate biases, and to build equity into making comparisons between applicants. For example, require letters of recommendation only for finalists, minimize numbers of letters of recommendation required, and ensure letters can come from a broader spectrum of recommenders (not just faculty). Alternatively, drop the requirement of letters of recommendations altogether, and ask directed questions of reviewers to obtain only the information needed and to standardize the process and answers to decrease inequities in recommender responses.
	Reviewers	Reviewers should be diverse and should be provided training on affinity bias, implicit/explicit biases, and racial, gender, and cultural biases in traditional application metrics. DEIAJ objectives should be clear during reviewer training, as should goals of using holistic processes for selecting diverse cohorts.
	Reviews	Programs should employ holistic application evaluation procedures guided by clear rubrics designed to minimize potential bias. Application reviews should strive to identify potential in students and should differentiate between student ability/potential and opportunity afforded students.

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Institutions, Native Alaskan Serving Institutions, Tribal Colleges, and two-year institutions like community colleges, because this is where a large proportion of talented URM students study (Table 1). For example, from 2001 to 2009, HBCUs produced 39% of all STEM undergraduate degrees earned at US colleges and universities by African American students (Owens et al., 2012), and 11 of the top 12 universities producing Black/African American physicists are HBCUs (AIP, 2020). Overall, MSIs account for 20% of all US STEM degrees, and nationwide more students are enrolled in MSIs than non-MSIs (NASEM, 2019). In California, 70% of all students pursuing higher education are community college students, and 60% of them are students of color, primarily Latina/o/x and Black (Sengupta and Jensen, 2006). Therefore, ocean science undergraduate research programs could diversify their student participants through targeted recruitment efforts focused on this diverse and typically untapped talent pool. Not only would targeted recruitment at MSIs increase the diversity of student participants, but in many cases it would also diversify the exposure of these students

TABLE 1. Continued...

PROGRAM COMPONENTS	STRUCTURAL CONSIDERATIONS	RECOMMENDATIONS
Final Selections	Diversity and Equity as Goals	Equitable and holistic processes should be built into final selections, with the goals of selecting a more diverse cohort and giving opportunities to those with potential who may not otherwise have such opportunities.
Safe Environments	Safety, Culture, and Environment	Consider the cultures and environments of the labs, offices, programs, housing situations, transportation options, community and field experiences, and other people and spaces students will experience. This should include physical and emotional safety and special consideration for sexual assault and sexual harassment (SASH) risks, prevention, and support. Educational training should be provided for students, project coordinators, staff, and mentors regarding the risks that disproportionately impact women, students, and staff from marginalized and minoritized backgrounds. Include SASH prevention and response, and safe toilet stops as integral parts of emergency preparedness and safety orientation for students, mentors, and staff.
	Support Structures and Emergency Response Protocols	Develop and widely disseminate comprehensive codes of conduct, emergency response protocols, information about SASH and bias response teams, points of contact, and reporting procedures to all points of contact (including those who are mandatory reporters).
Mentoring and Professional Development	Mentors and Staff	Training for mentors and staff should include inclusive mentoring, collaboration across difference, valuing all ways of knowing and being, recognizing biases, your holistic model, DEIAJ, SASH, and culturally relevant programming (e.g., ethical Indigenous engagement).
	Mentees and Students	Training for students should include the key topics for mentors and staff noted above as well as topics specific for students such as inclusive scientific communication, career awareness panels, graduate school preparation, research ethics, cohort-building, and technical skills training.
	Sustained Mentoring	Mentoring should be sustained beyond the program to maintain relationships, to help with retention, and to assist students as they navigate iterative academic and career challenges and opportunities. Program structure should also include ways for students to remain in touch.
Social and Emotional Support	Cohort Models	Eliminate the "lonely only" scenario by intentionally selecting for diverse cohorts of students and staff. Cohorts help create safety and community, and diverse representation of staff demonstrates commitment to DEIAJ throughout the organization.
	Social Belonging	By developing a sense of belonging, and a safe, inclusive culture, programs can improve persistence and success of diverse scholars. Engaging family, embracing culture and community, including equitable and inclusive group activities, and ensuring diverse cohorts of students and staff in programming are a few examples that can help create a sense of belonging for all.
	Science Identity	Create opportunities for students to develop their science identities, as this is essential to retention of diverse students in STEM programs. Programs can achieve this goal by expanding career awareness, opportunities for field and lab-based directed research, networking and public speaking opportunities, inclusion of cultural relevance and community-based science, social and environmental justice engagement, and inclusive scientific communication training, among others.
	Place-Based Opportunities	Not all students can or want to leave their families/communities to participate in high value research opportunities. Consider ways to engage students remotely, include cultural relevance and community-based approaches, and innovate in other ways to engage students from where they are.
	Cultural Relevance and Co-Creation	Engage students in the co-creation of their scientific endeavors and ensure cultural relevance in research opportunities. Consider family, community, and environmental and social justice connections as bridges, and actively and intentionally engage students to ensure their full participation in the knowledge enterprise.
	Timing of Programs	Consider timing of programs to ensure participation of students from a variety of academic calendars/schedules.

to STEM fields that may not be represented at their institutions. For example, most HBCUs do not offer degrees in geosciences (O'Connell and Holmes, 2011), meaning that there are likely HBCU students who might pursue ocean sciences, if only they had exposure to the field.

A successful model for targeted recruitment of MSI students is seen in The University of California (UC) UC-HBCU initiative (https://www.ucop.edu/uc-hbcu-initiative/). This program incentivizes UC faculty to engage with, and provide summer research opportunities to, HBCU students. In turn, the participation of HBCU students in UC summer programs has created an important pathway for many HBCU students to matriculate into UC PhD programs, with nearly 100 HBCU alumni entering UC PhD programs, including individuals that eventually transitioned to UC faculty positions. Similarly, to increase collaboration and research efforts between National Oceanic and Atmospheric Administration (NOAA) scientists and MSI faculty and students at the undergraduate and graduate levels, in 2001 NOAA created the José E. Serrano Educational Partnership Program with Minority Serving Institutions (EPP/MSI), establishing Cooperative Science Centers (CSCs) at four doctoral-degree-granting MSI academic institutions (encompassing 24 university campuses) (Cooper, et al., 2019). Each of these centers supports undergraduate and graduate students in a variety of ways to amplify their potential to develop science identities, expand their academic and professional networks, successfully complete their degree programs, and enter the workforce. For example, the NOAA Living Marine Resources Cooperative Science Center (NOAA LMRCSC) at the University of Maryland Eastern Shore has programming that includes active recruitment and mentoring of students, professional development activities, internships at NOAA labs, professional networking opportunities, and training in workforce competencies as well as full financial support for students' degrees (e.g., BS = 4 years; MS = up to 3 years, and PhD = up to 5 years; Chigbu et al., 2023, in this issue). The impacts of the LMRCSC's program on the future STEM workforce in marine and fisheries sciences are significant and impressive; between 2003 and 2022, 26% of Black/African American and 8% of Hispanic/Latino/Latina/Latinx scholars who received PhDs in marine sciences in the United States were supported financially through the LMRCSC (Chigbu et al., 2023 in this issue). Moreover, the direct connections to NOAA scientists and labs developed through LMRCSC internships, networking opportunities, and other workforce and professional development activities have proven to be a bridge to employment, with 41 graduates of the LMRCSC currently employed at NOAA (Chigbu et al., 2023, in this issue).

In addition, there is the NOAA EPP Center for Atmospheric Sciences – Meteorology (NCAS-M), established in 2001 at Howard University, which strongly focuses on increasing highly qualified, "workforce ready" graduates in STEM degrees aligned with NOAA's mission, including natural resource management, ocean policy, atmospheric sciences, and meteorology. These two impressive CSCs, along with the other lead MSIs and academic partners that encompass the NOAA EPP/MSI program, have contributed greatly to helping to diversify STEM graduate degrees awarded in the United States. Since the program's inception, more than 2,500 post-secondary degrees in NOAA-relevant fields have been awarded by CSC institutions (NOAA, 2022). The EPP/MSI also hosts an Undergraduate Scholarship Program that provides two years of academic financial support, networking opportunities, professional development, and two paid summer internships for each student at NOAA laboratories (Cooper et al., 2019). The EPP/MSI is a model of excellence that demonstrates the potential for outstanding results of intentional, long-term, well-funded, collaborative educational partnerships between MSI academic institutions and federal agencies.

Although targeted recruitment of MSI students will increase the diversity of participants in undergraduate research experiences, it is important to be cognizant of shifting demographic trends at these institutions. According to the National Center for Education Statistics (NCES, 2021), about a quarter of students enrolled at HBCUs in 2020 identified as non-Black, compared to 15% in 1976, and as of 2019, about the same percentage (25%) of HBCU faculty identified as White (Samayoa and Gasman, 2019). These statistics demonstrate a potentially shifting demographic at HBCUs that should also be considered, as recruiting solely at HBCUs does not guarantee that all applicants and/or faculty collaborators will be from URM groups.

From an HBCU perspective, targeted programs like these that provide professional development, financial support, mentorship, workforce development, and opportunities to conduct research in safe spaces are ones where students are more likely to succeed as undergraduates and to transition successfully to graduate work. Best practices show that programs providing hands-on and prolonged mentoring and training are the most successful at helping individual students develop a sense of belonging and a science identity that aids in retention and in building the ethnic diversity that the field has been striving to achieve (Cooper et al., 2019). For example, there are 89 PhD students and five master's students currently enrolled in University of California graduate programs who are alumni of the UC-HBCU Initiative; an additional 19 PhD students and 17 master's students have already graduated. Running programs that are highly effective at supporting the success of URM students requires more effort on the front and back end of the experience, but diversifying ocean sciences will require that all summer undergraduate research programs commit to these highly effective strategies.

Engage HBCU and MSI Faculty in Recruitment

Standard metrics of academic performance (e.g., GPA) used to select students for research experiences can be a barrier for URM students (Pierszalowski et al., 2021) and, as stated earlier, may not be reflective of abilities, as GPAs do not account for the conditions under which the grades were earned (e.g., students working full time to pay their way through school). Faculty members who work closely with students have insights into their passion and potential that GPA and other application metrics may not provide. As such, HBCU and MSI faculty are invaluable resources for identifying students who will most benefit from a particular summer undergraduate research experience (Table 1). For example, faculty leading The Diversity Project (https://tdp.eeb.ucla.edu/) at UCLA work with HBCU faculty at Hampton University, Howard University, University of Maryland Eastern Shore, Morehouse College, Florida Agricultural and Mechanical University, and University of the Virgin Islands to identify and invite students to apply to this research-intensive summer program, resulting in an outstanding and diverse group of applicants and participants each year.

Actively Engage in Recruitment

Students at HBCUs and other MSIs are bombarded by fliers, emails, and other passive, impersonal forms of outreach and communication. Moreover, the faculty at these institutions often have reservations about the climate and cultural differences between HBCU/MSIs and Predominantly White Institutions (PWIs), and the potential negative impacts that participating in research programs at a PWI may have on their students. For example, Black students enrolled at HBCUs experience more social climate and interracial stress when conducting research at PWIs than at HBCUs (Mitchell, 2018). In addition, trying to attract students from HSIs by highlighting basic research may not resonate with HSI students from scientific disciplines (e.g., medicine) that are viewed as benefiting their community. As such, it is important to personally engage with the cultural landscapes that faculty and students from different types of MSIs navigate (Garza, 2015, 2021) and engage them in similar ways you would engage valued research collaborators. This engagement can include activities such as in-person visits, inviting these faculty for a seminar at your institution, or engaging in scientific conference mentoring programs like the Association for the Science of Limnology and Oceanography (ASLO) Multi-Cultural Program or the SACNAS (Society for Advancing Chicanos/Hispanics and Native Americans in Science) Diversity in STEM Conference. Showing up and personally engaging with students and faculty from HBCUs/MSIs signals your values and shows them that they are important enough to invest your time in them.

Employ Holistic Recruitment Review

Although broadening recruitment strategies is essential to diversifying participants in undergraduate research programs, achieving the benefits of these recruitment strategies requires holistic review of student applications. Many undergraduate research programs view success and potential through a narrow lens, selecting students with high grades, previous research experience, and strong letters of recommendation. However, grades are not necessarily indicative of ability, as students from higher income backgrounds have more opportunity to not work and focus exclusively on their studies relative to low-income students (NCES, 2000), who tend to be from URM groups. Similarly, because these students work more, they have less time to engage in undergraduate research during the school year and so often lack the research experience and faculty relationships needed for strong letters of recommendations that come from such experiences. Composition of ocean science summer research experiences would diversify faster through the adoption of holistic application strategies that consider the potential of the individual and take into account important information such as the personal circumstances in which students earn their grades—a 3.0 GPA may be a more impressive achievement for a student working 20 hours a week than a 3.5 from a student with no work obligations. Research also demonstrates that letters of recommendation can introduce bias (Bernstein et al., 2022). For example, URM students, on average, receive weaker letters of recommendation, and readers pay less attention to their letters of recommendation than to those of White students (Rothstein, 2022), leading to some programs dropping letters altogether from their application processes. Instead, they are asking for references and sending out tactical questions to obtain the pertinent information needed to make a comprehensive review (Sloan and Haacker, 2020). Including information about work hours and about personal challenges in summer program applications will allow selection committees to view accomplishments in light of the context in which they were earned. Similarly, understanding the biased writing and reading of letters of recommendation for URM students will allow committees to be mindful of such biases as they evaluate the letters (Table 1). The impact of holistic review is seen in the National Science Foundation (NSF) Graduate Research Fellowship Program (GRFP). When NSF adopted holistic review of GRFP applications, the diversity of recipients of this fellowship increased 62.5% over the span of a decade (Muller-Parker and Bourke, 2023), highlighting the impact of holistic review practices.

FINANCIAL ASSISTANCE

Provide a Meaningful Stipend

A recent study indicates that of undergraduates who were interested in but did not engage in an internship, 64% wanted to participate but could not, with financial considerations being the major

obstacle (Hora et al., 2020). Such financial issues are a major problem impacting aspiring students in ocean sciences (Isma et al., 2023; Kamer et al., 2023, both in this issue). Black and Latina/o/x students receive Pell Grants at a rate nearly twice that of White students (NCES, 2019), and financial constraints limit the entry of URM students into undergraduate research (Pierszalowski et al., 2021). In 2020, 74% of part-time and 40% of full-time US undergraduates were employed (NCES, 2022), and summer employment can be a critical part of paying for college. Although many internship opportunities are paid, a recent survey of college students reported that 33% of their internships were unpaid (Hora et al., 2020), a number that exceeds 50% for Black women in ocean sciences (Isma et al., 2023, in this issue). In recognition of these financial constraints, the NSF REU program requires a $600/week stipend, or $6,000 for a typical 10-week summer program. The NOAA Hollings Scholars program pays students $7,000 for their 10-week summer research experiences and also provides $3,600 to each student for summer housing. However, many programs offer much less. For those running undergraduate research experiences, investing your time in mentoring students is important, but it is also critical to secure funding to provide students engaged in undergraduate research experiences a meaningful stipend, increasing the ability of URM students to participate in your program.

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Cover Travel and Housing

Students participating in summer research programs often must travel away from home. Although many summer programs provide both housing and travel expenses for students, this support is not standard. Many nonprofits, including zoos and aquariums, provide a modest stipend but do not provide housing or travel expenses for students who are not local to their institutions. Such practices yield biased recruitment that favors local students from wealthy communities. Given that financial concerns are an important barrier to equitable access to participation in internship opportunities (Hora et al., 2020), to diversify ocean sciences, summer programs must provide funding and travel to all program participants. For example, the Woods Hole Partnership Education Program (PEP) and the NOAA Inclusive Fisheries Internship Program (IN FISH) both offer $6,000 stipends for their 10-week summer research internships, and also offer course credit and full support for travel, housing, and meals. Moreover, these expenses need to be paid for, up front, as many students don't have the resources to pay directly for travel expenses and then wait to be reimbursed, a common practice at many colleges and universities.

Cover the Hidden Expenses

Although providing a stipend, housing, and travel support is important, it may not fully cover the costs of participation in an ocean science-based undergraduate research program. For example, a student participating in an oceanographic cruise or international field work could require a passport. Low-income populations are substantially less likely to have previously traveled internationally, and White Americans are much more likely to have traveled internationally than Black Americans (Silver, 2021), indicating that passport ownership is complex and nuanced, and can include differences in economics, cultural and ethnic reasons, and possibly even racialized differences (e.g., immigration status). Moreover, people from the African-American South and Native American lands are also less likely to have passports (Chinni, 2023). Not only is lack of a passport a potential financial barrier, first-time passport applicants may not know the process and timing for applying for a passport. Programs that include international travel need to be prepared to alleviate the financial burdens and provide guidance to students who are first-time passport applicants.

Undergraduate research programs may also occur in climates or conditions that require the purchase of clothing, both for day-to-day use and for field specific applications. For example, a student from Arizona might not have a wardrobe appropriate for cooler, wetter climates such as Monterey, California, or Seattle, Washington. Students working on small boats might require foul weather gear. Students doing scuba- or snorkeling-based research may need to

purchase wetsuits and other equipment and may also have to pay for a diving physical to be approved to work in the field. These expenses can be significant, potentially totaling hundreds or thousands of dollars, as noted by Barber et al. (2023, in this issue). Abdel-Raheem et al. (2023, in this issue) also share examples of ways in which logistical and financial barriers (among many others) limit participation of underprivileged and minoritized students in ocean sciences, with the cost of learning to scuba dive and the need for paid research opportunities explicitly discussed.

To minimize the hidden costs of summer research experiences and to maximize participation of URM students, it is important to build these hidden costs into the budgets of summer programs. For example, The Diversity Project at UCLA, which includes scientific diving training, purchases wetsuits and snorkeling gear for students to keep, and maintains a supply of buoyancy compensators, regulators, and dive computers for students to use during the program (Barber et al., 2023, in this issue). Similarly, Hampton University is revitalizing its diving program by offering scuba lessons and covering the costs of renting the required equipment.

SAFETY AND INCLUSION

Have Policies and Procedures for Addressing Inappropriate, Unsafe, and Illegal Behaviors

In the absence of effective policies and accountability structures to create safe and welcoming environments, women and URM and other marginalized students and staff often experience hostile climates that discourage their future participation in the ocean sciences. Clancy et al. (2014) document the pervasiveness of sexual harassment and sexual assault (SASH) at field stations. A Women in Ocean Science (2021) report indicates 78% of women in ocean sciences reported sexual harassment in fieldwork environments, leading to the publication of two articles that include recommendations on how to address the increased SASH vulnerability in fieldwork settings (Ackerman et al., 2023; Osborne et al., 2023, in this issue). Similarly, URM students in STEM fields report a high prevalence of microaggressions (Harrison and Tanner, 2018; Anderson et al., 2020; Demery and Pipkin, 2021), which can discourage students and scholars from minoritized and marginalized backgrounds from continuing in STEM. Demery and Pipkin (2021) outline the ways in which students and colleagues from minoritized and marginalized backgrounds (especially women, and those who present with visible identities that differ from the local population) are at a disproportionate risk of harm, and in some instances, may experience life-threatening situations when in certain communities or field sites. Green et al. (2023) outline the ways in which toilet stops for women are often not considered when planning for fieldwork, and this need is not limited to urination, as all menstruating and/or lactating women need privacy and consideration. This can lead to stress, discomfort, humiliation, limitation of fluid intake, attrition of women from STEM, extreme vulnerability, and in some circumstances, heightened risk of attack (Green et al., 2023).

It is critical for summer research programs to include considerations of SASH prevention and response, the disproportionate risks of women and minoritized and marginalized individuals in the field, and safe toilet stops as integral parts of emergency preparedness and safety orientation for students, mentors, and staff. Leaders of summer programs need to pursue training to understand the challenges faced by women, URM groups, and other marginalized populations in their summer programs, and program mentors need mentoring on how best to build safety and sensitivity into their programs, foster success of all student participants, and provide emotional support when needed (Hofmann et al., 2023, in this issue). Similarly, there need to be orientation sessions for all program participants that focus on establishing and enforcing codes of conduct and proper training in the dissemination of institutional reporting procedures and establishment of emergency response as well as safety and sensitivity protocols (Demery and Pipkin, 2021; Green et al., 2022; Abdel-Raheem et al., 2023, in this issue; Ackerman et al., 2023; Osborne et al., 2023, in this issue). Moreover, all individuals in mandatory reporting roles should be clearly identified as part of all documentation and training for awareness of all participants, and also to minimize triggering unwanted reports, which can occur inadvertently.

Create a Sense of Belonging

Although identity and social integration influence the persistence of URM STEM majors (Wade, 2012), in many academic fields, including STEM, URM students are less likely to feel a sense of belonging and to develop a positive STEM identity than students from well-represented groups (Walton and Cohen, 2007; Zaniewski and Reinholz, 2016; Ito and McPherson, 2018; Rainey et al., 2018; Cooper et al., 2019). While active recruitment of URM students for summer programs is important for diversifying ocean sciences, it is also important to create a critical mass of students to avoid "the lonely only" effect that leads to feelings of isolation and marginalization (Malone and Barabino, 2009). Moreover, when numerically underrepresented, cues that communicate that students don't belong (e.g., microaggressions, lack of representation) can undermine their sense of belonging and motivation (Walton and Carr, 2012). In contrast, the social support of being in a cohort can increase a sense of belonging and safety in URMs (Tomasko et al., 2016). As such, ocean science undergraduate research programs could boost the success of URM student participants by recruiting a cohort of URM students and fostering community and belonging. Although such race-based recruitment is not permitted under federal law,

recruitment efforts can focus on type of institution (HBCU, MSI, community colleges), first-generation college students, and low-income students, which can often overlap the intersecting identities of URM students (Horn and Nuñez, 2000; Holmes et al., 2008).

Harness the Power of Diversity

STEM students report that meeting STEM professionals from similar backgrounds has a positive effect on their commitment to STEM careers (Kricorian et al., 2020). For example, Black students are more likely to pursue advanced math classes when taught by a Black math teacher (Klopfenstein, 2005). Consequently, undergraduate research programs in ocean sciences would benefit from the inclusion of diverse faculty and program staff. While lack of diversity in ocean sciences makes this goal challenging, race and ethnicity are only some of the many underrepresented identities that can lead to a feeling of isolation and lack of belonging. For example, White male faculty may be first-generation college students, from low-income backgrounds, have a disability, be neurodiverse, or be a member of the LGBTQ+ community. Sharing these marginalized identities with students in summer programs provides alternate avenues for developing identity specific connections, potentially increasing students' sense of belonging.

CULTURAL AND FAMILY SUPPORT

Engage with Student Families

Although identity and belonging play significant roles in STEM degree persistence for URM students (Wade, 2012), family plays a significant role in their choices of majors (Davis, 2010; Garza, 2015), persistence in STEM fields, and interest in pursuing graduate school (Pierszalowski et al., 2021; Monarrez et al., 2022). Thus, engaging the families of student participants in summer research programs represents an untapped resource for supporting the students' ambitions to pursue careers in ocean sciences (Behl et al., 2021). For example, the University of California San Diego/Howard University Partnership for Graduate Success Program invites and funds parents' attendance at the final research symposium where students present their work, a model that has been replicated by the marine-focused The Diversity Project at UCLA. Although inclusion of parents in summer program activities can represent a significant cost, other strategies employed by The Diversity Project are no cost, such as emailing parents to introduce the program and program staff and opening a line of communication for families to share concerns. The program also sends photos and videos to parents throughout the summer so that they can vicariously share in the experience.

Foster Cultural Inclusivity Rather Than Conformity

Western cultural stereotypes of STEM professions (e.g., White, Eurocentric, male) and beliefs regarding who can be a scientist can impact STEM aspirations (Thébaud and Charles, 2018). Science is dominated by a Western cultural perspective (Iaccarino, 2003) that requires students to conform to these Western standards. Such cultural mismatch can result in increased stress in URM students (Stephens et al., 2012a, 2012b), compromising their academic performances and/or leading to a disinterest in STEM (Pierszalowski et al., 2021; Green et al., 2023). To increase diversity in ocean sciences, it is essential to embrace cultural and community connections as well as different ways of knowing and learning in order to increase accessibility and relevance for students from diverse backgrounds. Even simple interventions like talking about institutional commitment to diversity and inclusion can significantly lower stress (Sladek et al., 2020). It is essential for faculty and staff leading undergraduate research experiences to develop students' cultural competencies as well as programmatic cultures that welcome and validate different cultural perspectives and life experiences; fostering feelings of cultural value and inclusion is likely to have important impacts that reduce student stress and promote higher achievement. Mandatory training should also be provided for students, mentors, and staff on topics such as inclusive mentoring, collaboration across differences, valuing all ways of knowing and being, biases, DEIAJ (diversity, equity, inclusion, accessibility, and justice), SASH, and culturally relevant programming (e.g., ethical Indigenous engagement).

MEET STUDENTS WHERE THEY ARE

Consider ways to engage students remotely, as some students may not have the interest or ability to be away from their homes, families, and/or communities for the length of summer programs or internships. During the Covid pandemic, many groups swiftly and successfully shifted to remote engagement for internships, using online chat services such as Slack to foster community and consistent communication, and employing Zoom and other video conferencing platforms for connecting cohorts of students, mentors, and staff (Sloan et al., 2020). Innovative approaches to field research and other technical and/or hands-on scientific opportunities included rotating smaller groups through field sites, staging pop-up field experiences, assisting with local/community-based data collection, virtual training of technical skills, and virtual mentoring, among many others that have proven to be effective alternatives to traditional, in-person cohorts (Sloan et al., 2020; Wendy Todd, University of Minnesota Duluth, *pers. comm.*, December 2023). The inclusion of cultural relevance, and intentionally meeting students where they are academically, socially, emotionally, physically, and even geographically, can go a long way toward mitigating barriers to participation for some students and helping to foster inclusivity and belonging, while demonstrating awareness and respect for diversity. Wendy Todd, Alaska Native scientist and cultural practitioner, assistant professor

at the University of Minnesota Duluth, and a guest editor of this special issue, includes cultural relevance, Indigenous language scholars, and community-based approaches in her summer programming for Indigenous and Native scholars, and innovates in other ways to engage students from where they are, including sending each participant environmental data collection tools to apply in local/community-based research (Wendy Todd, University of Minnesota Duluth, *pers. comm.*, December 2023).

ASSESSMENT

Track Outcomes to Demonstrate Success

Every undergraduate research program is an experiment that tests the hypothesis that program participation leads to positive career outcomes for student participants. In ocean sciences, positive outcomes would be evidenced by increased matriculation to graduate school, increased entry into the ocean sciences workforce, and similar metrics. However, few programs collect the data necessary to test this hypothesis, leaving this enterprise to education researchers and social scientists. In the absence of these data, gaps remain in demonstrating the effectiveness of our programs. Highly successful programs focused on diversifying STEM like the Meyerhoff Scholars Program collect longitudinal data that demonstrate the long-term impacts of their programs, such as program alumni being nearly five times more likely to complete a PhD program than non-program participants (Maton et al., 2016). Such efforts should be standard for undergraduate research programs in the ocean sciences.

Longitudinal tracking is more challenging than typical pre- and post-program assessments. However, there are mechanisms that can facilitate this data collection. Students provide social security numbers to receive a stipend, and with permission, these numbers can be used to look at long-term educational outcomes in the National Student Clearinghouse (https://www.studentclearinghouse.org/). Other strategies involve establishing personal connections, such as creating a LinkedIn group for program alumni, a WhatsApp group chat, or other mechanisms that facilitate the long-term connections needed for tracking longitudinal outcomes. Such data are essential in order to understand whether programs are serving the needs of URM students, and collection of these data should be required by agencies that fund such programs.

SUSTAINED MENTORING

Make a Lifetime Commitment to the Success of Your Students

Undergraduate research programs are an important first step in the pathway to careers in geosciences (Plymate et al., 2005). While direct faculty mentoring is essential during the research experience program, the relationships should not end when students return to their home institutions. Ensuring the success of URM students aspiring to careers in ocean sciences will require the scientists who lead these programs to partner with the students' home institutions and make sustained commitments to the success of their mentees (Table 1). Students need guidance on applying to graduate school and for fellowships. They require help focusing their interests and identifying labs for graduate study. They benefit from continued support and encouragement to sustain the level of excitement they developed for the field during their summer research experiences. Just as funding agencies like NSF require mentoring plans for postdoctoral scholars, they should also require long-term mentoring plans for students in NSF-funded undergraduate research programs. This mentoring is time consuming and should be compensated. Achieving this will require funding agencies supporting programs focused on diversifying STEM to allow faculty to budget summer salary and/or course release to facilitate long-term mentoring of undergraduate research program participants, as such engagement yields higher student success (Kraft et al., 2023).

TIMING

Find Times That Work for All Students

US colleges and universities operate on two disparate academic calendars: a semester system and a quarter system. Schools on the semester system typically dismiss in mid to late May, while schools on the quarter system dismiss in early to mid June. The summer recess for almost all institutions exceeds 10 weeks, allowing flexibility in the timing of summer research programs to accommodate students from both semester and quarter systems. Failure to consider the timing of programs can exclude a large number of diverse students. For example, at the University of California, nearly 44% of the 88,285 students who entered in the fall of 2023 come from URM groups (UCOP, 2023), and most of these students are on the quarter system. Programs at schools on a semester system that operate on schedules that exclude students on the quarter system thus exclude large numbers of diverse students. Although UCLA runs on a quarter system, The Diversity Project at UCLA employs timing that can accommodate both students on the semester and the quarter system, as running the program strictly on the quarter system would exclude all HBCUs and most MSIs. Achieving this goal requires program flexibility, potentially allowing students to arrive a few days late or miss parts of the early program while taking finals. It can also require creativity on the part of the students, such as getting permission from instructors to take finals early or remotely to facilitate participation. These small compromises can allow summer programs to serve the largest number of students to the greatest impact.

CONCLUSIONS

A Broader Approach to Inclusion

Although this paper focuses on challenges facing URM students in ocean sciences, and suggests approaches to help alleviate these challenges, it is important to note that URM students are not the only marginalized groups in the field.

Individuals with disabilities (Bower et al., 2023, in this issue), neurodiverse individuals (Wilson et al., 2023, in this issue), non-traditional students (Woodworth-Jefcoats et al., 2023, in this issue), and non-swimmers (Barber et al., 2023, in this issue) are just some of the many identities that can feel marginalized in ocean sciences. In addition, URM students are not a monolith. One formula may be better than what is currently in place, but there is not a one-size-fits-all solution. Moreover, it is important to consider intersectional identities and socio-emotional and other support needs of diverse cohorts. A program that excels at supporting students of color may still alienate students because they are queer, neurodivergent, or the first in their family to attend college. Developing programs that best serve students will require flexibility, a recognition of the many ways groups are marginalized in STEM, and a true devotion to providing individualized opportunities and support for students in the program.

Re-envisioning how we structure undergraduate research experiences is an important step toward building a culture of inclusion that unlocks opportunities for marginalized groups to fully participate in ocean sciences and harnesses the power of a diverse ocean science workforce. However, the number of undergraduate geoscience field experiences is decreasing nationwide (Cotton, 2009; Riggs et al., 2009; Benson, 2010). Thus, it is important for the ocean science community to explore other approaches that target students during the academic year and early in their academic journeys to maximize exposure and access to ocean science careers (Benitez-Nelson et al., 2023, in this issue). Achieving these goals will require everyone in the ocean sciences community to re-examine, rethink, and re-imagine how we are developing the next generation of diverse ocean scientists and creating an environment where all can thrive and equitably contribute their talents to solving the ocean's most pressing problems.

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