A more representative community of ecologists

Ecologists play a crucial role in providing solutions to the challenges facing the world. For most of the history of the field, however, the science of ecology has been pursued by white men, and increasingly, by white women. This lack of diversity is untenable today, not only because it is socially unjust, but also because solving environmental problems requires diversity. Ecology as a science is an extremely rewarding and fun career choice for many, but how can the field recruit a more diverse workforce to do this important and gratifying work? Attracting and retaining future ecologists of color is the focus of this Forum.

How do young people choose a career in ecology and environmental sciences? For many ecologists, environmental scientists and managers, and future natural resource professionals, an early field experience provides a crucial introduction and gateway. A sojourn at a field station, an extended field trip, or field expedition has introduced many of today's professionals to their fields, but at the same time, a growing literature documents problematic behavior, discrimination, and other forms of harassment that have been far too frequently reported, and little attention has been given to conscious or implicit exclusion of students from diverse backgrounds.

In their lead article, Bowser and Cid, two leading researchers and long-time champions of diversity in ecology, build on experience in long-running programs as well as the literature to diagnose challenges facing diverse youth, and present approaches to encourage, rather than discourage, further engagement. They describe affirmative and creative measures that foster a sense of inclusion and community among young scholars; this sense of belonging and empowerment allows many to advance to studies and careers in ecology and environmental science.

In the subsequent six papers, authors explore topics either responding to, or inspired by, the lead paper. They explore alternatives to a field experience as a gateway to a career in ecology or environmental sciences through, for example, data science or the social sciences. Other comment papers describe challenges faced in the next phases of an academic career, barriers faced by specific cultural groups and the approaches, challenges, and outcomes of programs aiming to increase the diversity of the environmental STEM workforce. All responses sound a clarion call for change to hear and value different voices and perspectives to be heard and valued. These include (1) structural and cultural change to our institutions and reward structures; (2) developing and nurturing personal relationships among students and their mentors, within teams and in internships; (3) making entry to ecology inviting and making advancement in ecology free from systemic barriers; and (4) broadening our vision of ecology, and the ways we learn about the world's ecosystems.

The Ecological Society of America, the home for *Ecological Applications*, is committed to the diversity, equity and inclusion needed to tackle environmental challenges in unity (https://www.esa.org/esablog/2020/09/24/time-for-action-esa-initiates-a-diversity-equity-inclusion-and-justice-deij-task-force/). The world needs all available talent and perspectives to meet environmental challenges today. *Ecological Applications* has long published occasional papers on the profession of ecology and never ones more important or timely than these. The editorial team is proud to provide an outlet for the voices of our field, in all its current, if inadequate, diversity and honored to host the passionate and committed views of our authors.

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Developing the ecological scientist mindset among underrepresented students in ecology fields

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Abstract. How do students discover ecology? Answering this question is essential for diversifying the environmental workforce because scientific disciplines, such as ecology, are often not discovered until students enter academia and are exposed to different disciplinary options. Ecology, and many of the environmental sciences, have persistent and alarmingly low numbers of underrepresented minorities (URM; African American, Hispanic American, Native American, and Pacific Islanders), while other science and technology fields have shown progress in diversification. Why does such underrepresentation persist in environmental disciplines? Social factors such as sense of belonging, science identity, implicit biases, and stereotypes all have been explored and are known to influence the participation of URM students in science. The unique role of the field experience in environmental sciences as a "rite of passage" and "authentic" research experience is one important influence on how URM students experience ecology. Interventions using social elements such as belonging and sense of place are demonstrated ways to broaden participation particularly in environmental science fields, yet dramatic underrepresentation still persists. Here we review known factors affecting and enhancing the recruitment and retention of URMs in the sciences and focus on comprehensive strategies shown to be effective recruiting URM students into the environmental workforce.

Key words: *applied ecology; ecology mentoring; education interventions; environmental workforce; field experience; training diverse ecologists; underrepresented minorities in science.*

Introduction

The diversity within the environmental workforce does not reflect the human communities they serve. To date, minorities and persons of disabilities (URM) remain significantly underrepresented proportional to their numbers in the United States population in Science Technology Engineering and Mathematics (STEM) fields (NCSES 2021). Progress on increasing participation for minorities continues to lag in the earth sciences, including geosciences, ecology, and other natural resource fields, while the representation of white women in those same sciences has increased consistently (Ortega et al. 2006, Taylor 2017, NCSES 2021).

How do URM students discover ecology disciplines? As background, in 1992, the Ecological Society of America (ESA) surveyed the diversity of its membership (Lawrence et al. 1993*a*). At the time, the data showed <5% ethnic diversity in ESA members. Approaching the ESA centennial in 2015, more than 20 yr later, ESA membership had reached at most 9% (Beck et al. 2014). The same survey also assessed how members had first become interested in ecology (Lawrence et al. 1993*b*). Sixty percent of the respondents had discovered ecology at an early age by participating in some guided field experience program and 32% were introduced to the discipline by a college professor. More recent data in 2015 continued to show the importance of mentors and field experiences in their discovery of ecology.[4]

Minority communities are not less interested or engaged in the environmental issues associated with ecology as a whole (Leiserowitz et al. 2018). The impacts of global climate change and associated environmental problems tend to be concentrated in communities of

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[4] https://esa.org/history/biographies/ecological-richness-diverse-contributors-of-diverse-contributions/

color (Otto et al. 2017) and the juxtaposition of poor communities of color and environmental toxins laid the foundations for environmental justice research, policies, and activism (Bullard 2018, Pearson and Schuldt 2018). Recent data indicate that environmental awareness is steadily increasing among ethnic minorities (Leiserowitz and Akerlof 2010, Taylor 2017), and that the underrepresentation of minorities in ecology is not from some inherent disinterest in the environment for those minority populations.

The need to make the environmental workforce match the increasingly diverse demographics of human communities has prompted research inquiry on what factors specifically affect URM students' career choices in environmental science fields. For environmental careers, elements influencing URM engagement include many different factors such as family support (Armstrong et al. 2007), participation in guided experiences in nature appreciation (whether in urban or more natural field sites; Aloisio et al. 2018), exposure to careers in ecology (Morales et al. 2020), connecting environmental study in some way to interests in solving local and global community problems that affect minorities (Bowser et al. 2020), and field research experiences as high school or college students in any type of environmental setting (Flowers et al. 2016, Burrow 2018, O'Connell et al. 2018, Beltran et al. 2020). All of these experiences can lead URM students into further study of the environment. However, even with engagement by good mentors, URM students face additional barriers that include a lack of connection between the scientific field research opportunities, and life in their own communities (Hugo et al. 2013) in ways that do not promote comfort and engagement in studying environmental issues of interest (Miriti 2019).

Here we focus on how to infuse cultural and social elements as a part of ecological education objectives to engage URM students in ecology and environmental science. Our objectives are to (1) review foundational literature and research focused on URM participation in ecology, (2) compare single factor (focus on science) with multifactor (integrated with social factors) ecological programming approaches, (3) provide a framework and guidelines for adopting comprehensive and innovative approaches to URM engagement in applied ecology fields, and (4) suggest future strategies for research and practice.

Our literature review focused on elements identified by ecologists as important to their own professional development such as (1) the "rite of passage" of the field experience, (2) sense of belonging to a group and the outdoor culture, (3) sense of place in ecology instruction, and (4) identifying as a scientist or field ecologist (Fig. 1, Appendix S1). Research on field experience programs has shown that active learning can help broaden participation in environmental education, but the focus has been primarily on increasing student self-efficacy and less on integrating the human dimensions into

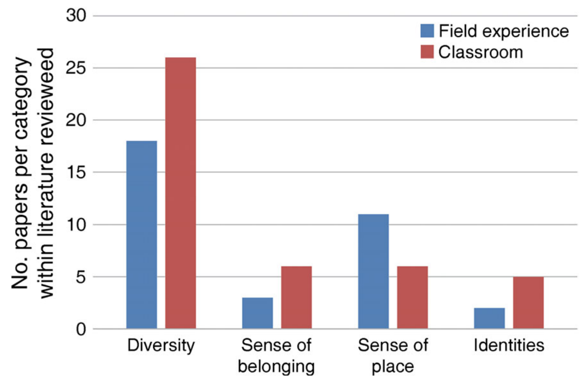

FIG. 1. Literature review results for field experience (n = 31) and classroom/theory papers (n = 43) focusing on (1) diversity, (2) sense of belonging, (3) sense of place, or (4) identities in relation to STEM education are shown on the x-axis and number of papers per category within the literature reviewed are shown on the y-axis).

developing a scientist identity (Ballen et al. 2017, O'Connell et al. 2018). A wealth of research on identity, belonging, and place attachment exists in the social science literature (Yeager and Dweck 2012, for example); however, these approaches have not been applied to the field experience and most of the relevant papers lie on the boundaries of ecology, science learning, and URM recruitment.

We have structured our discussion in three parts: *Part 1: The Field Experience*; *Part 2: Brief Interventions*; and *Part 3: Identity and Mindsets. Part 1* explores the role of the field experience as an introduction to the discipline of ecology and the current widespread underlying emphasis on elements of learning ecological science (as reviewed in Smith et al. 2019). *Part 2* outlines single and multiple factor interventions that introduce URM students to science in different ways and how such approaches lead to a combination of science learning targets and social science metrics such as belonging and identity. Finally, *Part 3* discusses the combination of social elements with core ecological concepts that can be structured in field experiences, can lead to ecological scientist mindsets that connect across multiple cultures around environmental learning and a sense of identity as a scientist.

Part 1: The field experience

Many academic and professional ecologists recall their first field experience as the moment when they felt that a career in field-based ecology was for them (Bowser et al. 2012). Such field experiences are often part of the broader impacts of ecological research to foster the social connections that play important roles in advancing ecological careers. Over the last three decades, the National Science Foundation's Broader Impacts requirements for research proposals (NSF 2020), Ecological Society of America's (ESA) environmental education professionals, and the American Association for the Advancement of Science's Vision and Change initiative, have all emphasized addressing the human dimensions in ecology (Brewer and Smith 2011, Cid and Pouyat 2013, Cid and Bowser 2015, Skrip 2015, Austin and Smith 2018, Berkowitz et al. 2018, Hansen et al. 2018). The National Science Foundation defines Broader Impacts as "...the potential to benefit society and contribute to the achievement of specific, desired societal outcomes..." (NSF 2020). Criteria for broader impacts as measures of society impact are often used to express some connection to diverse audiences or without any sense of belonging to the complex multicultural nature of society (Skrip 2015). However, in most field experience programs the integration of broader impacts and associated social interactions to create and promote trust and self-confidence in students is often lacking or needs development.

Sense of belonging is often overlooked as a part of the broader impact spectrum of a mindset of resilience where URM students develop an "...emotional response to academic or social challenges that is positive and beneficial for development..." (Yeager and Dweck 2012). The success of using "sense of belonging" interventions to improve recruitment and retention of URM students in science fields has also documented development of leadership skills (Walton and Cohen 2011). Similar interventions can be applied to create bridges for URM students to pursue a broad array of ecological science careers (Kudryavtsev et al. 2012, Russ et al. 2015, Mourad et al. 2018, Halliwell et al. 2020).

The latest literature suggests concern that the persistent underrepresentation of minorities in ecology is due to the culture of ecology as a discipline (Rainey et al. 2018, Miriti 2019). Since environmental study often requires field work, research has focused on internal factors associated with the rites of passage connected to the field experiences that create a sense of identity and belonging as an ecologist (Morales et al. 2020). Field experiences, whether a formal field class or research experience in outdoor settings, are considered a critical part of how students choose to enter the environmental workforce (Kloser et al. 2013, Flowers et al. 2016, Thompson et al. 2016, Fleischner et al. 2017, Berkowitz et al. 2018, Beltran et al. 2020). Many programs require students to have research experiences and professional organizations often rate these experiences as critical for employment (Haynes and Jacobson 2015). The field experience for applied ecology professions is a pivotal experience that can be a barrier, or an enabler, of student participation especially for underrepresented groups. The connection between appreciation for issues of global environmental concern (climate change, environmental justice for example) and the pursuit of ecological study at the college level has not been effectively made for most URM students (Taylor 2017, Hansen et al. 2018).

The most comprehensive effort to date to elevate the human dimensions in field experience programs as well as in undergraduate ecology curricula has been the 2018 ESA endorsement of the Four-Dimensional Ecology Education curricular framework (4DEE) (Klemow et al. 2019). The 4DEE framework promotes the discussion of human–environment interactions (human impact and codependence) in the teaching of all ecological topics in undergraduate and graduate environmental coursework (Ecological Society of America 2020). The 4DEE stresses the importance of science communication, field work experience and data/technology skills as consistent and critical parts of such instruction. The 4DEE curriculum focuses on what content to cover in college courses to better address the needs of societal-environmental problem-solving (Smith et al. 2019). Bringing human dimensions into ecological studies and field experiences is complex and, outside of urban field experiences, does not appear to be a widely used in ecology and potentially could engage more URM students (Russ et al. 2015, Taylor 2017, Mourad et al. 2018).

Part 2. Brief interventions

The literature indicates that brief interventions (short interval) can have an impact on science learning gains for students and promote the recruitment and retention of underrepresented groups in the sciences (Walton and Cohen 2007, 2011). Such brief interventions, as defined by Walton and Cohen (2011) focus on a single factor intervention (such as a field experience) or combine multiple interventions that include both class-based science learning and semester-long project-based teamwork (Fig. 2). Single factor interventions, however brief (i.e., not sustained over long periods), can have significant impact on student performance in science; multifactor interventions affect long term retention and identity as a scientist (Walton and Cohen 2011, Davis et al. 2012, Halliwell et al. 2020).

Multifactor interventions that blend sense of place, sense of belonging, team building, and other social elements with science are difficult to execute in the field. Emphasizing a balance of science and project-based learning approaches (Thompson et al. 2016, Burrows 2018, Mourad et al. 2018, Halliwell et al. 2020), where the team itself is an integral part of the process, can be fundamentally different than a research experience for undergraduates (REU) experience. Ecological field experiences with an emphasis on multifactor interventions can change how all students learn (Singer 2019) and improve URM student participation (Kudryavtsev et al. 2012, Russ et al. 2015, Carpi et al. 2017).

Multifactor interventions can be relatively short and intense in a field or professional setting and result in high URM recruitment that often is not the case for longer interventions and research experiences (Diaz Eaton et al. 2016). An example of a multifactor intervention is the Rocky Mountain Science and Sustainability Network's (RMSSN) academy, started with a five-year grant from the National Science Foundation to

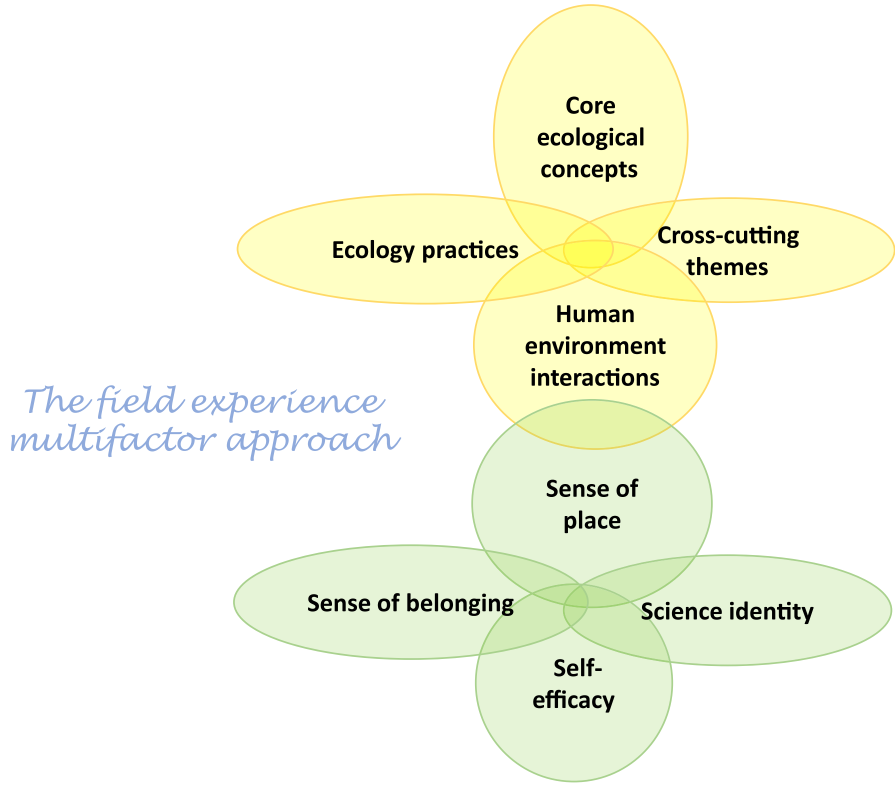

Fig. 2. Multiple factor interventions. Ecological science elements (yellow; as outlined in current ESA-endorsed 4DEE curriculum) integrate with social science elements (green) as part of the ecology field experience to provide intercultural connections.

G. Bowser and M. A. Brown in 2009 (NSF DBI0956059; DBI#1624191), to form a research coordination network in undergraduate biology education (RCN-UBE). RMSSN was an informal learning program to teach ecology and environmental sciences, with several distinct goals: (1) engage underrepresented students in a field experience to have them build capacity in designing experiments around core ecological concepts, (2) provide a team-based experiences to build confidence in understanding data design and scientific inquiry; (3) build a sense of belonging for all students to be a part of science inquiry, and (4) provide critical thinking skills and data analysis around a sense of place associated with applied ecological principles. Connecting local ecological issues to global issues, and engagement in citizen science has been a valuable component and a critical assessment component for students post RMSSN academy (Gretzel et al. 2014, Halliwell and Bowser 2019, Halliwell et al. 2020; Fig. 3).

The RMSSN multifactor intervention starts with the application process that prioritizes students with a leadership background and interest in global environmental issues over grade point average or other metrics. Applicants share how they view environmental issues as well as their own assessment of what a leader is. The RMSSN application avoids questions that put emphasis on field skills (e.g., have you ever been camping?) or easy-to-learn skills (do you know how to set up a tent?). Such reframing of questions about skills can raise the applicants' perception of their ability to be leaders in a novel or unfamiliar setting. Using social skills, such as the ability to work with or lead a group of peers (e.g., have you ever led a team of your peers on a novel adventure?), as the core metric for a field experience, elevates a different pool of applicants who see themselves as leaders regardless of their experience in actual field settings. This first step is critical, yet often is overlooked, as the application process itself can discourage students from even considering the experience and/or the field of ecology itself. These early interventions can bring different students into ecology by focusing on skillsets they can define themselves (I see myself as a leader because. . .) regardless of whether the student is from an urban apartment building or rural farming community.

Another multifactor intervention program, now 25 years old, is the Ecological Society of America's Strategies for Ecology Education, Diversity and Sustainability (SEEDS) program. The award-winning SEEDS program recruits primarily upper-level science majors with leadership potential from long established university-based SEEDS student chapters and clubs. SEEDS students participate in group field trips to an important ecological site with faculty mentors, attend a leadership gathering at the annual ESA conference, where they are

FIG. 3. Developing sense of place in project teams conducting research in the Rocky Mountain Science Students Network (RMSSN) academy program through highlighting cultural connections that enhance student and sense of belonging in science. Photo credit: Gillian Bowser.

assigned mentors, and engage in scientific and social activities. A series of short multifactor interventions (3–4 d to 1 week) take place over a year that include developing professional skills, group projects, social components, reflection, and sharing (Mourad et al. 2018). To date, one measure of the success of the SEEDS program is that 71% of the alumni have persisted in the environmental sciences and pursued environmental careers (Ahern-Dodson et al. 2020).

Moving beyond single-factor focus (on science) and incorporating social and cultural elements (belonging, identity) combined with science learning is well documented to shift student academic success in the sciences and increase their retention in science as a whole (Miriti 2020). Important steps toward diversifying the ecological disciplines thus include multifactor interventions that focus on URM students' sense of identity and belonging through cultural connections as well as field experiences.

Part 3: Identity and mindsets

In this paper, our goal has been to understand how to maximize the number of URM students who develop an ecological scientist mindset, i.e., a mindset that enhances their ability to understand ecological principles, engage in ecological research, and pursue professional careers in ecology. Ecology focuses on observing patterns in nature, species interactions, and environmental change (Reiners et al. 2013, Tewksbury et al. 2014, Barrows et al. 2016, Reiners 2016, McKeon et al. 2020). An ecological mindset is an outcome when observations of patterns are combined with developing a sense of identity and belonging within the field of ecology. As students build confidence in their ability to conduct ecological science, they begin to identify as scientists and expand their mindset toward addressing global environmental issues (Davis et al. 2012).

There are at least five elements to the effective multifactor intervention to recruit and retain URM students in ecology and develop their ecological scientist mindset: (1) recruiting students who have leadership potential and are interested in making a difference in society, (2) spending time developing the team spirit and sense of community with structured project-based learning including social exercises, (3) picking project ideas that can easily be connected to the cultural values and interests of URM students (Miriti 2019), (4) connecting the experience to different senses of place and of belonging for diverse cultures, and (5) incorporating innovative technology (Palumbo et al. 2012) or art visualization (Ellison et al. 2018) valued by the student age groups and cultures.

Field ecological research requires that ecologists be able to quickly integrate data collection and analysis methods to cope with unexpected environmental circumstances, disturbances and a wide range of unanticipated challenges. Thus, the training of all ecologists needs to promote the development of a "resilience mindset." Yeager and Dweck (2012) define a resilience mindset by four characteristics: (1) student goals, what drives students engagement in project-based learning using the students' own goals toward learning (eagerness to learn); (2) beliefs about effort, do they perceive themselves to have the natural talent needed, or perceive they lack some skill and thus fail to even engage in the experience; (3) attributions, ability to handle setbacks as part of the experience; and (4) learning strategies, unknowns and personal effort (try harder or give up).

Resilience mindsets respect the incoming student's culture and are critical dimensions of belonging and the lived experience, whether in urban or rural settings (Fleischner et al. 2017, Aloisio et al. 2018). When students self-organize a project, they can incorporate such lived experiences into research designs or team assembly. Yet, while such projects may have great risk of failure or non-significant results, the self-organized, project-based, learning framework itself can teach resilience and provide opportunities as well as develop observation skills that help students identify as being a scientist. Resilience is an important component of an ecological scientist mindset, especially when rooted in a sense of belonging and connections beyond just the science outcomes of a project; "…we learned how to observe the data and despite our inability to locate [the organisms]…we feel a special connection to the park itself." (student observer remarking on why Yellowstone was now a special place for her [Halliwell and Bowser 2019]).

Belonging, resilience, and sense of place can be enhanced using short creative interventions. Developing these traits can provide the bridge needed for URM students to connect with ecology, and create a sense of purpose that identifies with internal and cultural desires to make a difference. Such bridges are also important at pre-college levels and can help URM students enter college with an interest in the ecological sciences, already equipped with a sense of identity and belonging as an ecologist (Torres and Bingham 2008). Sense of place and sense of identity can be seen as elements of an ecological identity "Ecological identity focuses one's attention on environmental activities, green infrastructure, ecosystems, and biodiversity, including in urban places" (Kudryavtsev 2016). Identity, resilience, and ecological mindsets all lead to gains in student learning; retention in the discipline and movement into professional careers.

How do you hook students into ecology for life? To create an ecological scientist mindset for an audience of URM students requires a three-step intervention (Fig. 4) that starts with the recruitment process (applications are focused on finding students having leadership skills without a need for prior field experience that would eliminate many URM students [Step I]), continues with preparation of selected students to increase and strengthen their individual and cultural sense of place and belonging (Step II), and culminates in an inclusive field experience (Step III) that raises confidence and self-

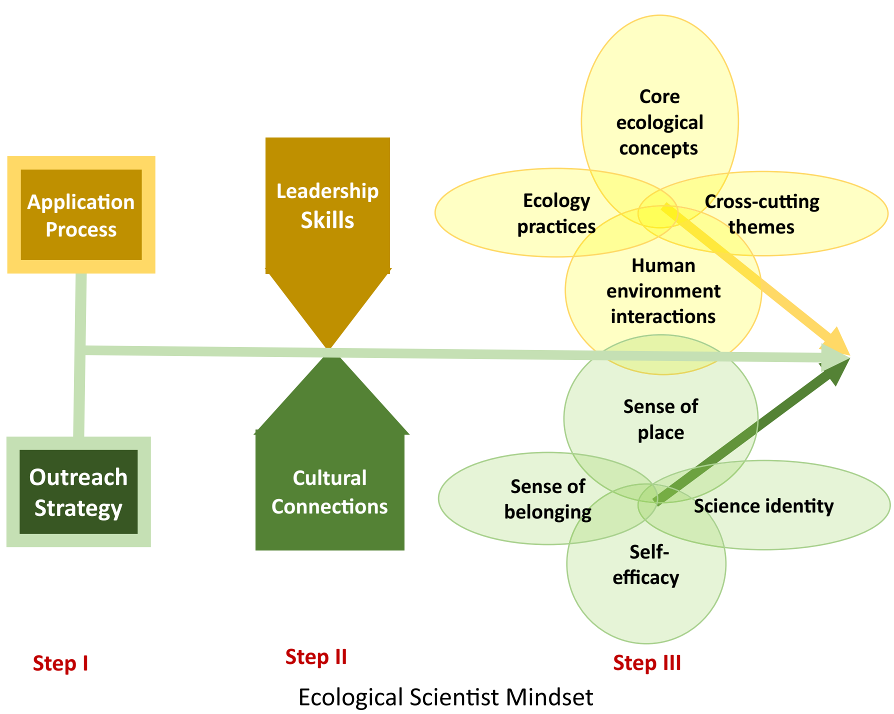

Fig. 4. Guide to multifactor brief interventions that link culture and science to create an ecological scientist mindset. The three steps of planning a field experience include: Step I, recruitment process; Step II, preparation of selected students; and Step III, field experience in which ecological concepts are combined with human dimension concepts. These three steps connect, as indicated by arrows, and culminate in an ecological scientist mindset.

TABLE 1. Student research program logic model for brief 4Cs designed interventions to bridge culture and science and enhance broader impacts to in student field research experiences.

Intervention step	Desired outcome	Measures of success
Step I: Recruitment	Comfort: URM students apply to program.	Increase in number of applications from URM students.
Step II: Student preparation	Connection: through assigned online research, all students develop cultural connection to proposed field site and engage their leadership skills in preparing for field experience.	Increased sense of place in student participants, especially for URM students. Students can articulate their cultural connection to the proposed research project.
Step III: Field experience	Confidence: students gain ecological knowledge and skills in performing field research to enhance their training as ecologists.	Increased self-efficacy through ability to design and test hypotheses in the field site. Increased sense of belonging to the community of ecologists, especially in URM students.
Ultimate goal: Ecological scientist mindset assessment	Capacity: Natural history observational skills, skills in designing and testing ecological hypotheses are developed.	Students, especially URM students, increase their ability to perform ecological work and continue to pursue environmental careers.

Notes: The 4Cs are comfort, connection, confidence, and capacity. All students accepted in the program need to be assessed pre-field experience for measures of success indicated.

efficacy, leading to an ecological scientist mindset (Table 1). Interventions that focus on retention of URMs in ecology can then be assessed for effectiveness across different cultural and racial ethnicities that together weave a pathway to an ecological mindset, centered in the student's cultural and/or racial identity.

The RMSSN intervention focused on creating resilience mindsets that involves URM students in the use of easily accessible and doable data collection techniques, utilizing cell phone technology, cultural stories, art, and citizen science. In contrast, the SEEDS intervention focuses on creating ecological identity through professional development, peer activities, and leadership in the sciences. The connecting principle for both interventions is social: the students need a sense of purpose and the ability and confidence to make a difference through their own actions as future scientists. Introducing social elements and sense of belonging attracted diverse students and created an environment within which they could succeed.

An exclusive focus on recruitment is not the solution for the underrepresentation in the sciences (Brewer and Smith 2011, Austin and Smith 2018). Diversity efforts need to be more than the individual faculty or administrators' passion. Successful interventions should be rooted in robust scholarship and evidence, not just notions about the barriers URM students might face in science. We see an emerging framework that focuses on enhancing four social characteristics (4Cs) in the targeted student population: comfort with ecological field experiences; connection to the study site through sense of place preparation; confidence through team building exercises and fieldwork engagement; and capability through comprehensive field research programs (Table 1). Building these interventions within existing field experience programs can help create an inclusive "rite of passage" experience for URM students and generate and maintain interest in the field of ecology early in their academic careers and into their professions.

FRAMING SOLUTIONS

Field projects and experiences that strive to reach diverse audiences (often school children) or engage historically black colleges and universities (HBCU) often fail or underperform because "one-way provisioning of science information [that]... Mostly will not work..." (Skrip 2015). Barriers to underrepresentation by a specific minority group can be subtle and hard to detect. The integration of cultural competency with traditional pedagogy needs to occur in ecology, especially in field settings, such as research stations or field camps, where the sense of belonging and identity experienced by majority demographic can create barriers for those from diverse cultural groups. Field experiences work when they are combined with team-building exercises that create a sense of belonging and provide that rite of passage for *all* students leading toward a lifelong passion for ecology (Thompson et al. 2016, Halliwell et al. 2020). The sense of place component works when combined with a connection to the students' family values/cultural heritage and upbringing that also creates a sense of belonging for participating students: "My people were here too and I am not the first!" (African American student response on discovering the story of Buffalo Soldiers in Yellowstone National Park [Halliwell and Bowser 2019]). Recent acknowledgements from land grant institutions of the prior sovereign nations lands upon which they sit represent one path that highlights the value of telling the stories that respect the importance of place (Lee and Ahtone 2020). Such stories help reconnect all students with the culture of the landscapes providing them with perspectives of the many diverse cultures embedded with the same landscape. Similar acknowledgments in field locations create that same connection to the cultural landscape, woven tightly around the ecological processes themselves and creating special bonds for different cultural and demographic groups. Groups that may have

Fig. 5. Fostering the ecological scientist mindset broadens the "club" to include women of color who identify as scientists (RMSSN faculty mentors - left to right: Tashiana Osborne, atmospheric scientist; Nikki Hoffman-Grant, plant ecologist; Gillian Bowser, wildlife ecologist; Omayra Ortega, mathematician). Photo credit: Gillian Bowser.

called the landscape home or trace historical routes or passages find meanings that connect to that sense of belonging and place. Mentoring models for diversity advocates and allies need to include stories that combine a sense of belonging and a sense of place that acknowledges the diversity of students entering academia today.

How can we ensure URM students will discover ecology and stay engaged? One way to make progress is to focus first on the student and then on the science. Developing resilience in students during that first field experience allows URM students to explore and discover new things, but also provides the tools they need to succeed as a minority in a majority cultural setting, even without explicit mentor or peer support (Ballen et al. 2017, Carpi et al. 2017, Hansen et al. 2018, Beltran et al. 2020).

Many URM faculty or professionals who received their academic degrees at predominately white institutions can clearly remember the first URM professor they had in a class regardless of the science discipline (Bowser et al. 2012). Similarly, they can also remember the first field experience where they felt welcomed as both a minority and ecological professional and thus, officially part of the "club" (Cid and Bowser 2015, Cid and Brunson 2020). Resilience mindset allows URM students to deal with, not just the process of discovery and exploration in sciences, but also the sense of belonging and participating in a rite of passage for ecological fields even if there is no one who looks like them in that field experience setting.

Focusing on the social elements (the 4Cs) and leadership mindsets can provide an effective framework for bringing new audiences into ecology despite it being a "discovered" major in academia. Why is this urgent and relevant today? Rapid global environmental change and increasing impacts of wildlife–human disease transfer provide an immediate sense of urgency since the people who are most impacted by these changes are the same who are left out or pushed out of science careers. Such affected groups need to have access to robust scientific data that are provided within their cultural context and by scientists who reflect those same audiences (Fig. 5). Communicating science in a culturally competent and relevant manner has never been more critical, especially as the world seeks solutions for global challenges like the COVID-19 pandemic and climate change. Developing an "ecological scientist mindset" in all students, regardless of cultural identity, promotes global wellbeing and sustainability. Moving forward, having a science workforce that is not only integrated but works together across cultural spaces and identifies as a science community with shared data knowledge should be our common vision for our students and future practitioners of science.

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Literature Cited

Ahern-Dodson, C. R., T. M. Clark, and J. A. Reynolds. 2020. Beyond the numbers: understanding how a diversity mentoring program welcomes students into a scientific community. Ecosphere 11:e03025. https://doi.org/10.1002/ecs2.3025

Aloisio, J. M., B. Johnson, J. D. Lewis, J. A. Clark, J. Munshi-South, S. Roberts, D. Wasserman, J. Heimlich, and K. Tingley. 2018. Pre-college urban ecology research mentoring: promoting broader participation in the field of ecology for an urban future. Journal of Urban Ecology 4:1–9.

Armstrong, M. J., A. R. Berkowitz, L. A. Dyer, and J. Taylor. 2007. Understanding why underrepresented students pursue ecology careers: a preliminary case study. Frontiers in Ecology and the Environment 5:415–420.

Austin, A., and D. Smith. 2018. Vision and change: unpacking a movement and sharing lessons learned. American Association for the Advancement of Science, Washington, DC, USA. https://www.visionandchange.org

Ballen, C. J., C. Wieman, S. Salehi, J. B. Searle, and K. R. Zamudio. 2017. Enhancing diversity in undergraduate science: self-efficacy drives performance gains with active learning. CBE Life Science Education 16:ar56.

Barrows, C. W., M. L. Murphy-Mariscal, and R. R. Hernandez. 2016. At a crossroads: the nature of natural history in the twenty-first century. BioScience 66:592–599.

Beck, C. K., C. S. Boersma, C. S. Tysor, and G. Middendorf. 2014. Diversity at 100: women and underrepresented minorities in the ESA. Frontiers in Ecology and the Environment 12:434–436.

Beltran, R. S., E. Marnocha, A. Race, D. A. Croll, G. H. Dayton, and E. S. Zavaleta. 2020. Field courses narrow demographic achievement gaps in ecology and evolutionary biology. Ecology and Evolution 10:1–13.

Berkowitz, A. R., C. Cid, J. Doherty, D. Ebert-May, K. Klemow, G. Middendorf, T. Mourad, and B. Pohlad. 2018. The 4-Dimensional Ecology Education (4DEE) Framework. Report to the Ecological Society of America. http:/esa.org/4dee

Bowser, G., S. A. Green, S. S. Ho, and P. H. Templer. 2020. Educating students in solutions-oriented science. Frontiers in Ecology and the Environment 18:171.

Bowser, G., N. S. Roberts, D. R. Simmons, and M. K. Perales. 2012. The color of climate: ecology, environment, climate change and women of color-exploring environmental leadership from the perspective of women of color in science. Pages 60–67 *in* D. R. Gallagher, editor. Environmental leadership in practice: a reference handbook. Volume 1. Sage Publications, Thousand Oaks, CA.

Brewer, C., and D. Smith. 2011. Vision and change in undergraduate education: a call to action. American Association for the Advancement of Science, Washington, DC, USA. https://www.visionandchange.org

Bullard, R. D. 2018. Dumping in Dixie: race, class, and environmental quality. Third edition. Routledge, New York, New York, USA.

Burrow, A. 2018. Teaching introductory ecology with problem-based learning. Bulletin of the Ecological Society of America 99:137–150.

Carpi, A., D. M. Ronan, H. M. Falconer, and N. H. Lents. 2017. Cultivating minority scientists: undergraduate research increases self-efficacy and career ambitions for underrepresented students in STEM. Journal of Research and Science Teaching 54:169–194.

Cid, C. R., and G. Bowser. 2015. Breaking down barriers to diversity in ecology. Frontiers in Ecology and the Environment 13: 179.

Cid, C. R., and M. W. Brunson. 2020. Engaging faculty in preparing students for non-academic environmental careers. Frontiers in Ecology and the Environment 18:52–53.

Cid, C. R., and R. V. Pouyat. 2013. Making ecology relevant to decision making: the human-centered, place-based approach. Frontiers in Ecology and the Environment 11:447–448.

Davis, E., G. Bowser, and M. A. Brown. 2012. The Global Mindset: engaging multicultural students in multidimensional learning. Pages 891–899 *in* D. R. Gallagher, editor. Environmental leadership in practice: a reference handbook. Volume 2. Sage Publications, Thousand Oaks, CA. 1988–2011

Diaz Eaton, C., D. Allen, L. A. Anderson, G. Bowser, M. A. Pauley, K. S. Williams, and G. E. Uno. 2016. Summit of the research coordination networks for undergraduate biology education. CBE—Life Sciences Education 15:mr1. https://doi.org/10.1187/cbe.16-03-0147

Ecological Society of America 2020. The four dimensional ecology education framework. Ecological Society of America, Washington, DC, USA. https://www.esa.org/4dee/framework

Ellison, A. M., et al. 2018. Art/Science collaborations: new explorations of ecological systems, values and their feedbacks. Bulletin of the Ecological Society of America 99:180–191.

Fleischner, T. L., et al. 2017. Teaching biology in the field: importance, challenges and solutions. BioScience 67:558–567.

Flowers, S. K., K. M. Beyer, M. Perez, and D. B. Jeffe. 2016. Early environmental field research career exploration: an analysis of impacts on pre-college youth apprentices. CBE-Life Sciences Education 15:ar67.

Gretzel, U., E. B. Davis, G. Bowser, J. Jiang, and M. A. Brown. 2014. Creating Global Leaders with sustainability mindsets—reflections from the RMSSN Summer Academy. Journal of Teaching in Travel & Tourism 14:164–183.

Halliwell, P., and G. Bowser. 2019. A diverse sense of place: citizen science as a tool to connect underrepresented students to science and the national parks. Mountain Views Cirmount 13:45.

Halliwell, P., S. Whipple, and G. Bowser. 2020. 21st Century climate education: developing diverse, confident, and competent leaders in environmental sustainability. Bulletin of the Ecological Society of America 101:e01742. https://doi.org/10.1002/bes2.1664

Hansen, W. D., et al. 2018. How do we ensure the future of our discipline is vibrant? Student reflections on careers and culture of ecology. Ecosphere 9:e02099.

Haynes, N. A., and S. Jacobson. 2015. Barriers and perceptions of natural resource careers by minority students. The Journal of Environmental Education 46:166–182.

Hugo, R., W. F. Smythe, S. McAllister, B. Young, B. Marring, and A. Baptista. 2013. Lessons learned from a K-12 geoscience education program in an Alaska native community. Journal of Sustainability Education 05:5.

Klemow, K., A. Berkowitz, C. R. Cid, and G. Middendorf. 2019. Improving ecological education through a four-dimensional framework. Frontiers in Ecology and the Environment 17:71.

Kloser, M. J., S. E. Brownell, R. J. Shavelson, and T. Fukami. 2013. Effects of a research-based ecology lab course: a study of non-volunteer achievement, self-confidence and perception of lab course purpose. Journal of College Science Teaching 42:72–81.

Kudryavtsev, A. 2016. Developing an ecological identity. https://naaee.org/eepro/blog/sense-place

Kudryavtsev, A., M. E. Krasny, and R. C. Stedman. 2012. The impact of environmental education on sense of place among urban youth. Ecosphere 3:29.

Lawrence, D. M., M. M. Holland, and D. J. Morrin. 1993*a*. Profiles of ecologists: results of a survey of the membership of the Ecological Society of America. Part I. A snapshot of survey respondents. Bulletin of the Ecological Society of America 74:21–35.

Lawrence, D. M., M. M. Holland, and D. J. Morrin. 1993*b*. Profiles of ecologists: results of a survey of the membership of the Ecological Society of America. Part II. Education and employment patterns. Bulletin of the Ecological Society of America 74:153–169.

Lee, R., and T. Ahtone. 2020. Land Grab Universities. Expropriated indigenous land is the foundation of the land grant university system. High Country News, Paonia, Colorado, USA. https://www.hcn.org/issues/52.4/indigenous-affairs-education-land-grab-universities

Leiserowitz, A., and K. Akerlof. 2010. Race, ethnicity and public responses to climate change. Yale University and George Mason University, New Haven, Connecticut, USA. Yale Project on Climate Change. http://environment.yale.edu/uploads/RaceEthnicity2010.pdf

Leiserowitz, A., S. Rosenthal, and M. Cutler. 2018. Latinos and global warming's Six Americas. Yale Program on Climate Change Communication. Yale University, New Haven, Connecticut, USA.

McKeon, S., L. Weber, A. J. Adams, and T. L. Fleischner. 2020. Human dimensions: natural history as the innate foundation of ecology. Bulletin of the Ecological Society of America 101: e01656.

Miriti, M. 2019. Nature in the eye of the beholder: a case study for cultural humility as a strategy to broaden participation in STEM. Education Science 9:291.

Miriti, M. 2020. The elephant in the room: race and STEM diversity. BioScience 70:237–242.

Morales, N., K. B. O'Connell, S. McNulty, A. Berkowitz, G. Bowser, M. Giamellaro, and M. Miriti. 2020. Promoting inclusion in ecological field experiences: examining and overcoming barriers to a professional rite of passage. Bulletin of the Ecological Society of America 101:e01742.

Mourad, T. M., A. F. McNulty, D. Liwosz, K. Tice, and F. Abbott. 2018. The role of a professional society in broadening participation in science: a national model for increasing persistence. BioScience 68:715–721.

National Center for Science and Engineering Statistics (NCSES). 2021. Women, minorities and persons with disabilities in science and engineering report. National Science Foundation, Alexandria, VA, USA. https://ncses.nsf.gov/pubs/nsf21321/

NSF. 2020. National Science Foundation Broader Impacts criterion. https://www.nsf.gov/pubs/policydocs/pappg20_1/pappg_2.jspIIC2d

O'Connell, K. E. B., K. Hoke, and R. Nilson. 2018. Report from the field on the design, outcomes and assessment of undergraduate field experiences. Technical report. Oregon State University, Corvallis, Oregon, USA.

Ortega, S., A. Flecker, K. Hoffman, L. Jablonski, J. Johnson-White, M. Jurgensen-Armstrong, R. Kimmerer, M. Poston, A. Socha, and J. Taylor. 2006. Women and minorities in ecology II (WAMIE II) committee report. https://www.esa.org/esa/wpcontent/uploads/2012/12/wamieReport2006.pdf

Otto, I. M., D. Reckien, C. P. O. Reyer, R. Marcus, V. LeMasson, L. Jones, A. Norton, and O. Serdicany. 2017. Social vulnerability to climate change: a review of concepts and evidence. Regional Environmental Change. 17:1651–1662.

Palumbo, M. J., S. A. Johnson, F. M. Mundim, A. Lau, A. C. Wolf, S. Arunachalam, O. Gonzalez, J. L. Ulrich, A. Washuta, and E. M. Bruna. 2012. Harnessing smartphones for ecological education, research and outreach. Bulletin of the Ecological Society of America 93:390–393.

Pearson, A. R., and J. P. Schuldt. 2018. A diversity science approach to climate change. Psychology and Climate Change:95–124. https://doi.org/10.1016/B978-0-12-813130-5.00005-9

Rainey, K., Dancy, M., R. Mickelson, E. Stearns, and S. Moller. 2018. Race and gender differences in how sense of belonging influences decisions to major in STEM. International Journal of STEM Education 5:10.

Reiners, W. A. 2016. The Cowles-Cooper tradition under Murray F. Buell: a personal retrospective. Bulletin of the Ecological Society of America 97:291–300.

Reiners, W. A., D. S. Reiners, and J. A. Lockwood. 2013. Traits of a good ecologist: what do ecologists think? Ecosphere 4:1–22.

Russ, A., S. J. Peters, M. E. Krasny, and R. C. Stedman. 2015. Development of ecological place meaning in New York City. Journal of Environmental Education 46:73–93.

Singer, S. 2019. Six decades of the National Science Foundation's commitment to undergraduate research. Scholarship and practice of undergraduate research 3:16–20.

Skrip, M. 2015. Crafting and evaluating broader impact activities: a theory-based guide for scientists. Frontiers of Ecology and the Environment 13:273–279.

Smith, M. K., C. Walsh, N. G. Holmes, and M. M. Summers. 2019. Using the Ecology and Evolution-Measuring Achievement and Progression in Science assessment to measure student thinking across the Four-Dimensional Ecology Education framework. Ecosphere 10:e02873.

Taylor, D. E. 2017. Racial and ethnic differences in the students' readiness, identity, perceptions of institutional diversity and desire to join the environmental workforce. Journal of Environmental Studies and Sciences 8:152–168.

Tewksbury, J. J., et al. 2014. Natural history's place in science and society. BioScience 64:300–310.

Thompson, S. K., C. J. Neill, E. Wiederhoeft, and S. Cotner. 2016. A model for a course-based undergraduate research experience (CURE) in a field setting. Journal of Microbiology and Biology Education 17:469–471.

Torres, L. E., and B. Bingham. 2008. Fixing the leaky pipe: increasing recruitment of underrepresented groups in ecology. Frontiers in Ecology and the Environment 6:554–555.

Walton, G. M., and G. L. Cohen. 2007. A question of belonging: race, social fit, and achievement. Journal of Personality and Social Psychology 92:82–96.

Walton, G. M., and G. L. Cohen. 2011. A brief social-belonging intervention improves academic and health outcomes of minority students. Science 331:1447–1451.

Yeager, D. S., and C. S. Dweck. 2012. Mindsets that promote resilience: when students believe that personal characteristics can be developed. Educational Psychologist 47: 302–314.

Supporting Information

Additional supporting information may be found online at: http://onlinelibrary.wiley.com/doi/10.1002/eap.2348/full

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Broadening the ecological mindset

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Abstract. Over the past three decades, the Harvard Forest Summer Research Program in Ecology (HF-SRPE) has been at the forefront of expanding the ecological tent for minoritized or otherwise marginalized students. By broadening the definition of ecology to include fields such as data science, software engineering, and remote sensing, we attract a broader range of students, including those who may not prioritize field experiences or who may feel unsafe working in rural or urban field sites. We also work towards a more resilient society in which minoritized or marginalized students can work safely, in part by building teams of students and mentors. Teams collaborate on projects that require a diversity of approaches and create opportunities for students and mentors alike to support one another and share leadership. Finally, HF-SRPE promotes an expanded view of what it means to become an ecologist. We value and support diverse career paths for ecologists to work in all parts of society, to diversify the face of ecology, and to bring different perspectives together to ensure innovations in environmental problem solving for our planet.

Key words: broadening participation; data science; ecologies; grand challenges; near-peer mentoring; teamwork.

Introduction

How do people discover ecology and how does that process influence the face of ecology? These are questions posed by Bowser and Cid (2021) (henceforth "B&C"), wherein they describe an "ecological mindset" and focus on how it can be solidified by field experiences. We agree with B&C that their logic model focusing on the "4C's" (*comfort* with ecological field experiences, *connection* to the study site through sense of place, *confidence* through team-building exercises and fieldwork engagement, and *capability* through comprehensive field research programs [italics as in B&C]) can provide an entrée for minoritized or marginalized students into an ecological mindset. Here, we complement the focus in B&C's 4C's on fieldwork and field experiences by exploring other pathways into it. Alternative paths that occur in tandem with or separate from field experiences may broaden the ecological community to include students who may place a lower priority on fieldwork or may be unable to work in the field. Our thoughts about broadening the ecological mindset and alternative paths into it derive from our roles as mentors and program directors of the Harvard Forest Summer Research Program in Ecology (HF-SRPE).

Ecology or ecologies?

Before considering paths into an ecological mindset it is helpful to understand how others may perceive the field of ecology. Ecology certainly is "[t]he branch of biology that deals with the relationships between living organisms and their environment...[and] the relationships themselves, esp. those *of* a specified organism" (OED 2020: 1.a.; italics in original), but it is also (since 1908) "[t]he study of the relationships between people, social groups, and their environment; (also) the system of such relationships in an area of human settlement" (OED 2020: 1.b.) and (since 1963) "[t]he study of or concern for the effect of human activity on the environment; advocacy of restrictions on industrial and agricultural development as a political movement; (also) a political movement dedicated to this" (OED 2020: 2.). More broadly, ecology is used in an attributive sense, relating ecological or environmental concerns in, for example, artistic, architectural,

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economic, educational, or political activities (OED 2020). Although many prominent and classically educated ecologists have embraced this diversity of ecologies (Strong 2008), others have been much more cautious (Burke and Lauenroth 2009, de la Rosa 2009).

The many broad definitions of ecology suggest that a similarly diverse set of pathways into ecology will broaden participation in the field. For example, in the last 20 years, ecology sensu stricto has become an increasingly data-intensive science (Peters et al. 2014); in the early 1980s, Long Term Ecological Research sites annually produced kilobytes of data collected by hand in the field and manually entered into computers, whereas today's sensors automatically compile gigabytes-to-terabytes of data every day. Analysis and synthesis of these types of data and those amassed by other large-scale collaborative observation networks have greatly expanded the range of important and interesting ecological questions. Answering such questions and addressing any of ecology's "Grand Challenges" (National Research Council 2001) is far beyond what a single researcher can accomplish on their own, whether in the field, greenhouse, laboratory, or with a single personal computer. Indeed, data science, as well as software engineering, remote sensing, or simulation modeling provide different paths into ecology careers for minoritized (and other) students. These paths, like those focused on lab- or mesocosm-based ecological research can coincide with field experiences.

In the last three decades, HF-SRPE has been at the forefront of expanding the ecological tent for minoritized and marginalized students by offering a diversity of paths to a broader ecological mindset. At its inception in the early 1990s, HF-SRPE focused almost entirely on field research and associated rites of passage for a small number (5–10 students/yr) of almost entirely white students. As the program has evolved to encompass ecological data science and other fields that contribute to ecological knowledge (e.g., modeling and software engineering) or apply it in other fields (e.g., hydrology, soil science, epidemiology and public health; McDevitt et al. 2020), it has more than doubled in size (20–30 students/yr) and the proportion of minoritized students in it has increased steadily to its current ≈50% (McDevitt et al. 2016).

Increasing inclusion through resilience

The "resilience mindset" (sensu Yaeger and Dweck 2012) that B&C identify as a crucial characteristic for ecologists can be extended to these other pathways into ecology. Its key attributes—student goals, beliefs about effort, attributions, and learning strategies—solidified by self-organized and self-designed research projects can be cultivated in any research setting. Certainly development of observational skills, a sense of place, and inclusion in a community of ecologists can happen in the field. But recent discussion around Black Birders Week highlighted how the development of a resilience mindset may happen more naturally outside of a field experience. This may be especially true for minoritized or marginalized students who may feel physically or emotionally unsafe when they are in rural field sites where intense discrimination and systemic racism are commonplace, but even urban field sites can be unsafe (Dowtin and Levia 2018). Although ecologists working in universities in the United States and Western Europe take for granted that LBGTQ+ students are safe in the field, inclusive field courses simply should not be held in the ≈70 countries where homosexuality is still illegal. In addition, the very nature of field experiences may present physical barriers to accessibility that prevent many students from participating.

At the same time, field research very much remains a core part of ecology, and it is up to all of us to develop a more resilient society in which minoritized or marginalized students are safe and welcome in rural and urban field environments. How? First, field programs need to have clear and enforced codes of conduct that address racism, similar to recommendations to combat gender-based harassment at field sites (Nelson et al. 2017). Second, mentors and programs need to be ready to advocate for their students, as powerfully demonstrated by Dowtin and Levia (2018) and Demery and Pipkin (2021). Third, our experience in HF-SRPE shows the effectiveness of developing diverse student-mentor teams to work together and support one another.

The importance of teams

Ecological research, like that in other STEM fields, now is frequently done in diverse teams organized not only around field campaigns or networks of field sites but also in working groups at synthesis centers or "in the cloud" (Baron et al. 2017). Ecologists who represent the broad range of human diversity not only should have complementary skills and expertise but also need to develop abilities for working in heterogeneous teams.

As HF-SRPE has expanded the ecological tent, we have also shifted from the classic "one mentor one student" apprenticeship model of undergraduate research to collaborative, team-based projects with multiple students and multiple mentors (McDevitt et al. 2016). Within a team, some students may focus on fieldwork while others focus on lab work or computational modeling. Thus, students are exposed to different aspects of the ecological mindset while building mastery and identity in their niche. We assemble teams that include students new to research and students with prior research experience; the latter serve as "near-peer" mentors for the former. All the students share responsibility for study design and reporting results. Team-based work adds to the students' sense of belonging while also exposing them to issues of, and team-based solutions for, intellectual ownership, shared credit, and differential contributions that professional ecologists deal with every day on any project. It appears that this is also a workable model for staunching leaks in the STEM pipeline: our long-term assessment of HF-SRPE students has shown that >75% of them have gone on to graduate or professional schools and subsequent careers in ecology and environmental science (McDevitt et al. 2020).

On becoming an ecologist

Broadening the ecological mindset implies an expansion of the career paths valued by the field. Classic training in ecology is typically geared toward preparing students for academic careers. Key metrics of success for programs such as NSF's Research Experience for Undergraduates (REU) include the number of participants who publish papers, attend graduate school, and eventually become tenured faculty; meeting these metrics creates a positive feedback cycle in which an academic career path is seen as the only path to "success" in the field. Increasing the number of minoritized tenured ecology faculty is unquestionably an urgent goal. This goal could usefully be complemented by the creation and support of a community of "ecologists in practice" who build and travel diverse career paths in all parts of society. Expanding the definition of what an ecologist is and does will increase human diversity in our discipline and increase our collective power to understand and solve the pressing ecological questions and existential challenges of living together on our shared planet.

Literature Cited

Baron, J. S., et al. 2017. Synthesis centers as critical research infrastructure. BioScience 67:750–759.

Bowser, G., and C. R. Cid. 2021. Developing the ecological scientist mindset among underrepresented students in ecology fields. Ecological Applications: e02348. https://doi.org/10.1002/eap.2348

Burke, I., and B. Lauenroth. 2009. "Environmentalist" label not in our best interests. Frontiers in Ecology and the Environment 7:240.

de la Rosa, C. 2009. Ecologists, environmentalists, and the problem with labels. Frontiers in Ecology and the Environment 7:467–468.

Demery, A. J. C., and M. A. Pipkin. 2021. Safe fieldwork strategies for at-risk individuals, their supervisors and institutions. Nature Ecology and Evolution 5:5–9.

Dowtin, A. L., and D. F. Levia. 2018. The power of being persistent. Science 360:1142.

McDevitt, A. L., M. V. Patel, and A. M. Ellison. 2016. Insights into student gains from undergraduate research using pre/-post assessments. BioScience 6:1070–1078.

McDevitt, A. L., M. V. Patel, and A. M. Ellison. 2020. Lessons and recommendations from three decades as an NSF REU Site: a call for systems-based assessment. Ecology & Evolution 10:2710–2738.

National Research Council. 2001. Grand challenges in environmental sciences. The National Academies Press, Washington, D.C., USA.

Nelson, R. G., J. N. Rutherford, K. Hinde, and K. B. H. Clancy. 2017. Signaling safety: characterizing fieldwork experiences and their implications for career trajectories. American Anthropologist 119:710–722.

Oxford English Dictionary. 2020. Ecology, n. https://www.oed.com/view/Entry/59380

Peters, D. P. C., K. M. Havstad, J. Cushing, C. Tweedie, O. Fuentes, and N. Villanueva-Rosales. 2014. Harnessing the power of big data: infusing the scientific method with machine learning to transform ecology. Ecosphere 5:art67.

Strong, D. R. 2008. Ecologists and environmentalism. Frontiers in Ecology and the Environment 6:347–348.

Yaeger, D. S., and C. S. Dweck. 2012. Mindsets that promote resilience: When students believe that personal characteristics can be developed. Educational Psychologist 47:302–314.

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Underrepresented youth experience barriers prior to field experiences

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Abstract. Environment for the Americas has developed a model internship program that helps to recruit diverse youth for internship positions on federal lands and with non-governmental organizations. To improve the program, we have conducted almost a decade of surveys to examine the barriers diverse youth may face when applying for these positions and working at sites where staff, visitors, and other interns may be predominantly White. Our model has been very successful in addressing barriers, including those presented by Bowser and Cid within this Forum. Survey responses show that issues of connection, confidence, comfort, and capability can be addressed through considerations of culture, staff awareness of diversity, equity, and inclusion, training, communication, and mentorship.

Key words: applied ecology; environmental workforce; field experiences; training diverse ecologists; underrepresented students.

Introduction

Bowser and Cid (2021) identify the field experience as a critical factor that can impact retention of underrepresented minorities in the sciences, particularly ecology. Recruiting diverse youth has been a challenging goal for many science-based organizations, both governmental and non-governmental (Miriti 2019). Despite considerable effort, for example, members of all visible minority groups represented <18% of the permanent workforce at the US Fish and Wildlife Service in 2018 (State of the agency EEO program MD-715 status report, *available online*).[4] Concerted attempts to diversify land management agencies have not succeeded for a number of reasons. In this paper, we will focus on our experience with the unique motivations and barriers for Latino youth, although data from a broader program that includes other diverse participants are included as well. Among Latinos, first- and second-generation youth are more inclined to adopt their parents' occupational choices than their Anglo counterparts, and they are strongly influenced by the lack of peers and mentors in that field. Our previous studies show that 86% of Latino parents are interested in learning more about careers that benefit their offspring (Bonfield 2014). Yet, Latino representation in conservation careers is low, and parental familiarity with U.S. natural resource agencies and organizations is limited. As a result, Latino students and their families have few opportunities to engage with scientists that represent their own ethnicity and culture.

Environment for the Americas (EFTA) has been studying the persistent low recruitment and retention of diverse youth in the sciences since 2009. In partnership with several land management agencies, including the National Park Service (NPS), the Bureau of Land Management (BLM), the U.S. Forest Service, and the U.S. Fish and Wildlife Service, we have examined barriers to visitation at natural areas, interests in nature-based programs that could lead to natural resource careers, and ways to increase engagement by diverse audiences in STEM activities (Bonfield 2014). Participants in our programs are engaged in a broader diversity of positions than those described by Bowser and Cid (2021), who focus on ecology. Some of our students also work in ecology, but others participate in environmental education, cultural heritage projects, and other STEM fields, such as geology.

Because of earlier findings that highlighted the need for greater diversity among staff at natural areas, EFTA

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created an internship model designed to serve as a pathway to careers in natural resources and conservation.

Environment for the Americas uses a data-driven approach to inform its internship programs, from recruitment and the application process, to the experiences participants have at their work sites. We have developed a model that has been adopted by several federal agencies, such as the National Park Service, to improve their capacity to recruit diverse applicants, to support positive experiences, and to serve as a pathway to careers in STEM with federal agencies or other organizations. Our model integrates the following components: (1) an intensive and highly personalized recruitment and screening process to select the candidates best suited for each position, (2) low staff to intern ratio to provide participants with sufficient contact, interaction, and assistance, (3) staff who represent our interns, both culturally and linguistically, and who are also experienced in STEM, (4) professional support for travel, communication, compensation, and housing, as well as immediate support in case of incident or injury, so that participants can focus on learning, (5) an ongoing professional training program that supports participants before, during, and after their internships, (6) close work with staff and supervisors to assist them in working with issues of diversity, equity, and inclusion at their sites, (7) a blog site where interns share their experiences, build cohort connections, and network more broadly, (8) support for attending and/or presenting at professional conferences, (9) a peer mentor program that connects new interns with previous interns, (10) a career workshop that brings interns together to meet one another and professionals in the field, and to attend additional trainings, and (11) regular communication with both interns and site staff using multiple methods communication channels.

> I loved my Mosaics in Science experience, from the internship duties to meeting the other interns at the conference in Colorado. I have never connected more quickly to a scientifically-based community before. It was inspiring to see where everyone took their internships. My experience absolutely influenced my confidence and ambition to continue in science.
>
> Gabriela “Bella” (2017) (Student)

Since 2007, we have coordinated internship programs that connect college students and recent graduates with scientists, researchers, and educators at governmental and non-governmental organizations, providing valuable field experiences. During this time, we gathered over 500 surveys administered before, during, and after the field experiences. The results of these surveys show that many factors affect interest, create barriers, and influence participation in careers in natural resources and other STEM areas.

Methods

Environment for the Americas surveyed interns from three different programs: Latino Heritage Internship Program (LHIP), America’s Great Outdoors/Celebrate Birds/Celebra Las Aves Internship Program (AGO), and the Mosaics in Science Internship Program (MIS). LHIP and AGO are both programs for students of Hispanic or Latino descent. MIS is a STEM program for students of diverse races and ethnicities. Interns in each program are surveyed at three times; before commencing their internships, at the midpoint of their internships, and upon completion of the programs. The analyses in this report include data from 2013 up to pre-internship surveys in 2020; 578 total responses were collected.

The surveys include both quantitative and qualitative responses designed to assess participant satisfaction with the programs at each point in time, including career goals, awareness of federal jobs before and after the internships, barriers to participating, and other topics. Quantitative questions were asked as “Yes/No/Maybe” or on a Likert scale, where 1 is “Strongly Disagree” and 5 is “Strongly Agree.” Open-ended questions provide additional data, which were categorized for analysis. Though questions were mostly uniform, there is some variation depending on year and program.

Some inhomogeneities include variations in survey administration each year. For example, mid-internship surveys were not developed until 2016. Furthermore, diversity internship programs with the National Park Service (LHIP and MIS), began in 2015 and 2016 respectively, while Celebrate Birds was launched in 2012. Data from each program depend on its start date and the number of participants.

Pre-Internship Phase

Most interns who applied to our internship programs had never sought a position with a federal agency. Only 26.1% (57) of respondents had submitted applications to a federal agency prior to being accepted into one of our programs. A closer look at these interns reveals a connection between the likelihood of applying for a position with a federal agency and experience with the agency. For example, we found that the number of interns who applied to positions at national parks increased with the frequency of visitation to national parks. Only 15.8% of interns who had never visited a park had previously applied to a position. This percentage more than doubles for interns who visit parks frequently, more than once a year (35.9%). A large majority (75.4%) of interns who had applied for positions visit parks one or more times per year. Conversely, only 5.3% of these same interns had never visited a park.

This result echoes our previous research on visitation to national parks (Bonfield 2014). We found that, when underrepresented minorities had positive experiences at national parks, they were more likely to return. These favorable experiences clearly have positive impacts on visitors, leading to raised awareness of science careers, familiarity with the place as a potential work location, and for youth, a desire to pursue a STEM career (Fig. 1).

Pre-internship surveys administered before participants begin working show that, while the field experience may play a role in determining retention of underrepresented youth in natural resources, other factors earlier in the application process must also be considered. Just over one-third (38.2%) of respondents did not identify specific barriers to applying. The remainder identified at least one barrier, with family being a primary concern (17.1%; Fig. 2). This response includes parental preference that offspring not leave home at all, not move away from home for the 12-week program, or not move to a location that is difficult to visit. Of those who identified family as a barrier, 87.2% are Latino. Intern Ruby (Latino Heritage Internship Program 2020) explains the challenges:

> In Latino culture, it is very rare for kids to stray far from home, even more rare as a daughter. When applying for this internship I knew I would face challenges and that I would have been on my own in a sense. I am from California, and I only applied to programs that were in California, fearing that anything out of state would be too hard. I mapped every park I applied to, ensuring that my family would still be able to visit me, and it would be realistically affordable for them. My family is very tight knit. My brother and his family live only two houses away from me and my mom. I am the youngest of two and the first to fly a little farther from the coop, so this was new for my mom. My mom's youngest was moving 7 hours from her even if it was just for the summer. Aside from being 7 hours from home, my mom struggled with the fact that I was literally going to be disconnected digitally, which brought up safety issues for her. Unfortunately, my housing does not have cell service or wifi, so I am quite literally disconnected as soon as I get home. This worried her a lot; she even tried to convince me not to stay. She was not comfortable leaving me in a city where I knew no one and had no way of contacting her once I got home. This led to many tears and having to convince my mom that I would be fine, and I had to be courageous. It is hard when my support system is begging me not to stay, but I could not quit before I even had a chance to experience what this journey entailed. I promised her that if I ever felt like it was too much and I was too homesick, I would tell her, and she would be on the next flight picking me up.
>
> —Ruby

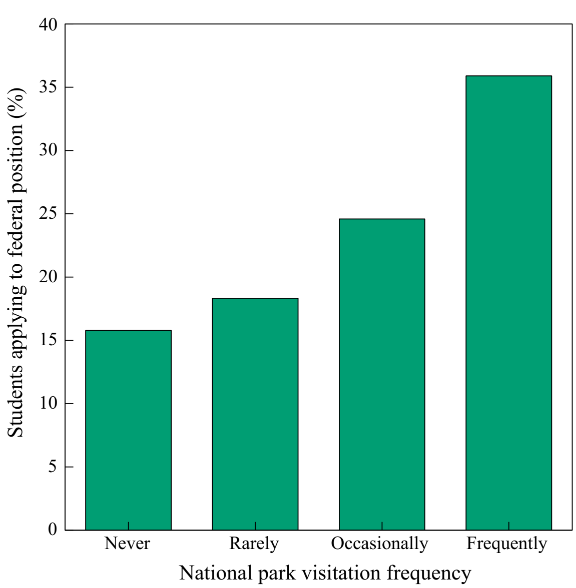

Fig. 1. A histogram of interns who applied to a position at a federal agency prior to their internship split into their park visitation frequency.

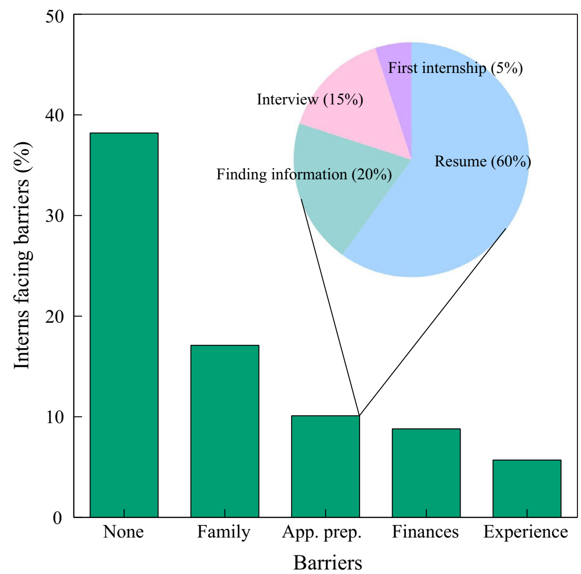

Fig. 2. A histogram of barriers interns faced to applying to internship programs. The inset pie chart breaks down the responses that went into application preparation. App. prep. stands for application preparation.

Ruby's experience is familiar to us. Many Latino applicants live with their families during college and after. For some, the internship is their first time to be away from home for an extended period. In our recruitment process, we explore this situation and use the responses to select work sites where interns are most likely to be successful. Our hiring process may even involve conversations with parents, who need assurance that their children will be safe.

Twenty-three interns (10.1%) identified the application process as a barrier. Of these, some applicants (60%) did not have resumes or felt their resumes needed to be revised. Others were challenged by the prospect of an interview, and some did not understand the position options on the program website. Finances and traveling to unfamiliar locations were also concerns.

Bowser and Cid (2021) also discuss the importance of intern comfort and confidence with their qualifications at the recruitment stage. Our surveys show that, across all applicants, only 5.7% (13 respondents) were concerned that they lacked experience, nine of these respondents applied to STEM positions, and 3% (seven respondents) had self-doubt.

Post-Internship Phase

Once interns complete their experiences, we administer a post-internship survey consisting of approximately 20 questions. This survey is designed to explore intern satisfaction with their position, knowledge gained about career opportunities, and ability to apply for federal jobs. Interns also rate host site knowledge of diversity, equity, and inclusion (DEI) on a Likert scale. Sixty percent of interns indicated that host site staff members were knowledgeable or very knowledgeable about the topics. While Bowser and Cid (2021) focus on sense of place and its importance to participant comfort, our results show a positive correlation between staff knowledge of DEI and mean intern comfort level ($r^2 = 0.81$; Fig. 3). Interns who rated host staff as very knowledgeable (5), agreed or strongly agreed that they felt comfortable at their site; a knowledgeable site staff led to a comfortable intern. The same is true on the other end of the spectrum. Interns who rated site staff knowledge of DEI 1 or 2 also rated their comfort as low (1 or 2). Also of note is the fact that interns who felt neutral about their site staff's knowledge were more likely to feel comfortable than those who felt their staff had low knowledge (54.8% vs 81.6% comfort).

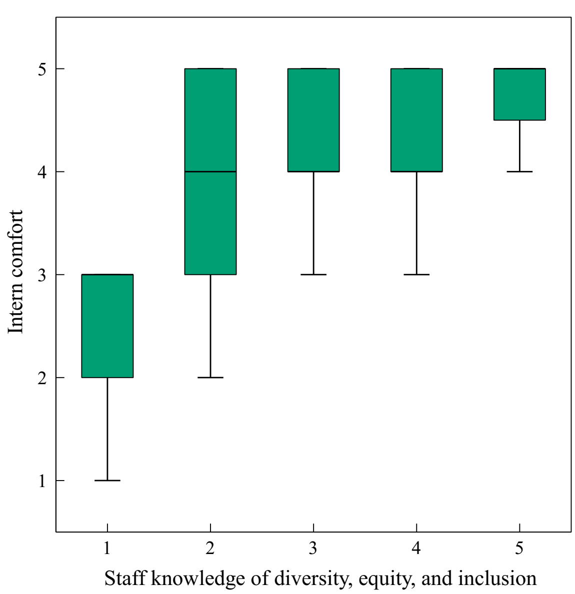

Fig. 3. Box and whisker plot relating intern comfort to staff knowledge of diversity, equity, and inclusion. Box plot components are median (center) 1st and 3rd quartile and maximum/minimum. Partial plots reflect small or skewed samples.

> I really enjoyed the Mosaics in Science program. The coordinators and staff I came in contact with were all so supportive and helpful. As a woman of color, I was having a really hard time getting any job in the environmental sector. My experience working at a National Park through this program really influenced my ability to get future positions in the environmental field. The week long conference where we got to meet all the other participants in the program was so valuable. To meet so many people of color who were interested and passionate about working in the environmental field was so powerful.
>
> Saba, 2017, State Agency

Intern comfort level during their internship may influence their interest in pursuing a federal agency career: more comfortable interns were more interested in continuing down the career path. For this reason, it may be important to train site staff on issues of diversity, equity, and inclusion. Additionally, the staff can make it clear to interns that they have received this training, so that interns know they have knowledge on the topics. These findings are consistent with Maria Miriti's (2020) research, which suggests that culturally competent faculty can improve diversity initiatives and retention of diverse students in STEM.

We asked interns to rate their comfort level at their job sites, as well as their interest in pursuing a career with a federal agency, such as the National Park Service. Similar to Bowser and Cid's suggestions, we found that the cultural competence of the intern mentor plays a role in participant comfort level (Fig. 4). Our data show a relationship between intern comfort during their internship and success of the internship as well as potential retention in the field. Of 117 intern responses, 85.5% (or 100 interns), felt comfortable working at their sites (Fig. 2). Similarly, 102 of the 117 (87.2%), expressed interest in pursuing a federal career. Approximately 75% of interns who felt comfortable at their sites also expressed slight to great interest in a federal career. About 50% of interns who felt comfortable (intern comfort = 4 or 5), indicated a strong interest in pursuing a federal career (Fig. 4).

Of interns whose responses were neutral, that is, they were neither comfortable nor uncomfortable during their experiences, 16.7% indicated slight disinterest in pursuing a federal career. Although the number of interns who were slightly uncomfortable at their sites was small (3.42%), they demonstrated the least interest in a federal

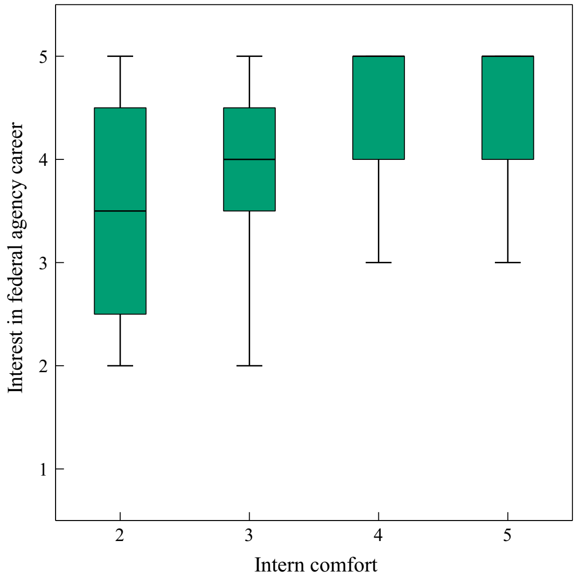

FIG. 4. A box plot relating intern interest in pursuing a career with a federal agency to their comfort at their work site.

agency career. These findings are similar to those discussed by Bowser and Cid (2021), though we find that intern comfort is also critical during the work experience.

Conclusions and Recommendations

The intensive approach described and analyzed here has proven successful in creating pathways to careers in STEM for diverse youth. Our programs reduce barriers to applying, lead to many interns reporting high comfort level at host sites (85.4%) and result in a high level of interest in continuing to pursue careers in their fields, including STEM careers, whether with a federal agency, through an advanced degree program or with a non-governmental organization.

> This experience definitely made me enthusiastic about a federal conservation career… Programs like Mosaics are absolutely essential for diversifying the federal conservation workforce. I am excited to see what the future holds for conservation work.
>
> Jeanie, 2018, Federal Agency

A recent survey (October 2020) of 44 youth who participated in Mosaics in Science (MIS) from 2013 to 2019 shows that this program is successful in long-term retention. Of these respondents, 36% are working in federal positions, and almost 75% of these positions are permanent. Though this number is just 27% of total participation in the program since 2013, it shows that diverse youth can be successfully recruited into natural resource careers (Table 1). Eight of the respondents (18%) are attending or have completed graduate school in fields including geophysics, ecology, climate justice, and other STEM and environmental fields. Over 90% of participants responded that MIS influenced their career decisions and also expressed how the program improved their confidence and motivation to stay in the STEM field.

TABLE 1. Current positions of Mosaics in Science alumni.

Position	*N*	%
Federal	16	36
Other STEM	13	30
Graduate student	8	18
Undergraduate student	3	47
Outside of field	2	5
State	2	5
Non-profit	1	2
Sum	44	100†

†Sum not equal to 100 because of rounding.

Bowser and Cid (2021) identified early field experiences as a critical gateway to careers in environmental science and management. We report here on long-running programs to recruit diverse youth into natural resource, STEM-oriented, and federal careers. Creating a successful first field experience, as the Environment for the Americas' interns are recruited for, requires skill and culture-based pairing of intern and project/site, ongoing program support for a wide range of intern needs, and support after the programs to aid the interns as they enter into their careers. It requires cultural competence in recruiting, selecting, assigning and supporting youth, and as data reported above show, cultural competence and sensitivity on the part of supervisors and mentors is also key. Interns also gain cultural competence through their programs, as many of them, as documented above, will intern in a natural environment, organization and cultural part of the country different from the one they grew up in. EFTA's approach focuses on supporting the quotidian needs of interns, housing, financial support, travel and other logistical requirements, so that they can focus on both cultural and technical learning. These programs implement specific capabilities and activities to enable the kind of positive experience Bowser and Cid (2021) advocate, and form a specific example of the general principles they champion.

Acknowledgments

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Literature Cited

Bonfield, S. B. 2014. Engaging latino audiences in informal science education. Thesis. Colorado State University, Fort Collins, Colorado, USA.

Bonfield, S., D. Dorta, and J. Vargas-Barriga. 2021. Underrepresented youth experience barriers prior to field experiences. Dryad, data set. https://doi.org/10.5061/dryad.cnp5hqc44

Bowser, G., and C. Cid. 2021. Developing the ecological scientist mindset among underrepresented students in ecology fields. Ecological Applications: e02348. https://doi.org/10.1002/eap.2348

Miriti, M. N. 2019. Nature in the eye of the beholder: A case study for cultural humility as a strategy to broaden participation in STEM. Education Sciences 9:291.

Miriti, M. N. 2020. The Elephant in the Room: Race and STEM Diversity. BioScience 70:237–242.

Open Research

Data (Bonfield et al. 2021) are available in the Dryad Digital Repository: https://doi.org/10.5061/dryad.cnp5hqc44.

Ecological Applications, 0(0), 2021, e02346

Addressing bias in faculty retention

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Abstract. The field of ecology in the United States is not fully harnessing the diverse perspectives of the American population. Two major limitations to advancing diversity and inclusion include insufficient awareness of biased attitudes and the lack of large-scale faculty engagement in diversity and inclusion programs. Academic institutions must recognize and value individuals that participate in diversity and inclusion programs. Valuing this work will motivate all ecologists to accept the responsibility for these efforts and not simply assume that the few minorities in their field can do this work.

Key words: bias in academia; ecology interventions; ecology mentoring; ecology workforce; excluded identities in science; training diverse ecologists.

Whereas much of this collection of papers focuses on undergraduates from diverse backgrounds entering the "ecological mindset" (e.g., Bowser and Cid 2021, Ellison et al. 2021), here we consider challenges to retention of diverse groups in ecology once in the faculty career stage. Although diverse and inclusive groups are more productive and innovative (Hong and Page 2004, Woolley et al. 2010, Nielsen et al. 2017, AlShebli et al. 2018), the field of ecology in the United States is not fully harnessing the diverse perspectives of the American population in all career stages of the academic workforce (Martin 2012, Arismendi and Penaluna 2016, Farr et al. 2017). Insufficient awareness of biased attitudes hinders the advancement of people of excluded identities (Iporac 2020). Ultimately, this fuels systemic racism at the institutional and structural levels leading to a lack of retention of persons of excluded identities.

Because of the interdisciplinary nature of the field, mentoring is essential to guide early career ecologists, making researchers of excluded identities particularly vulnerable to biased attitudes of more senior mentors. Even though biases can seriously limit effective progress in enhancing diversity, there is not enough space or training to improve biased attitudes in academia. Studies show that well-intentioned individuals that can often avoid biased responses fail to detect subtle racial biases when they occur (Monteith et al. 2001). Regardless of intentions, individuals can have difficulty when trying to avoid responses that are generated by processes that operate outside conscious awareness (Bargh 1997, 1999, Devine and Monteith 1999). Recognizing both extreme and subtle biases and the willingness to attribute biases to internal forces are critical for learning to control them (Monteith 1993, Bargh 1999, Monteith et al. 2002). However, these implicit biases and microaggressions resulting from them may be difficult to recognize because their impacts are often somatic, rather than cognitive (Menakem 2017). Left unchecked, these biases can have a serious impact on the careers of ecologists of excluded identities and those who lack adequate training to recognize and prevent biased behavior. However, addressing implicit bias in diversity, equity, and inclusion training can have mixed results (Jackson et al. 2014). In some instances, implicit bias training may result in adverse reactions such as increased triggering of stereotypes and exclusion of particular groups (Rudman et al. 2001). Care must be taken to reduce categorization that leads to intergroup bias (Nishii 2013) and that reduces the value of individuals to their race or gender.

Diversity initiatives and training focused on implicit bias suffer from the concept of bias itself, which emphasizes individual actions and the belief that making individuals mindful of their own biases leads to positive change (Applebaum 2019). Such a focus on individual actions can take attention away from institutional (i.e., advanced by social institutions, such as colleges and universities) and structural (i.e., advanced by interconnections between institutions) biases that perpetuate unfair

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power systems. Here we consider some of the institutional and structural biases faced by academic ecologists in the faculty career stage and discuss actionable ways forward to promote positive change towards inclusion. We acknowledge there are a wealth of challenges faced by ecologists from excluded identities leading up to a faculty job, but a thorough evaluation of them could easily exceed the space allotted to this set of papers.

Academic institutions set the values for their employees by setting standards for tenure and promotion. Although many institutions have goals to support diverse student bodies, requirements for tenure and promotion have not evolved to require participation in diversity initiatives, limiting the successful adoption of and broad participation in diversity and inclusion practices. Across fields, faculty of excluded identities disproportionally engage in diversity and inclusion activities (a.k.a. invisible service), although these activities do not help them acquire tenure and promotion (Jimenez et al. 2019). This can overburden faculty of excluded identities with commitments that limit their ability to focus on efforts that advance their research, which is often perceived as the most important determinant of their success (Perkins 2006). When ecologists were surveyed to determine their value of research, teaching, service, and outreach, research was assigned the highest value most consistently, followed by teaching, and service and outreach were least valued. Most importantly, the values respondents attached on behalf of their employers generally mirrored their own values (Perkins 2006).

Reflecting on personal experiences, the balancing of invisible service with other regular demands of academic life (e.g., teaching, research, nondiversity and inclusion-based committee work) can lead to diverse scientists contributing less in other forms of service to the field (e.g., peer review of manuscripts). This balance of a heavier load than experienced by White scientists generates a peer-review system that is likely to be less diverse and thus potentially more biased against diverse perspectives. In sum, this invisible service load leads to a cycle that limits the potential innovative contributions of diverse ecologists.

Addressing institutional biases could start with acknowledging the invisible service load placed on faculty of excluded identities. Institutional administrations and faculty writ large should support antiracist committees or centers on campuses. Faculty involvement with these groups should "count" towards evaluations for promotion similar to participation in other committees related to faculty governance (e.g., curriculum committee). A key goal of such a group on campus would be to normalize conversations about identity, so that issues of diversity, equity, and inclusion become day-to-day considerations rather than occasional topics of discussion. Ultimately, all faculty should value and promote a shared responsibility in advancing diversity and inclusion regardless of their identity (Jimenez et al. 2019).

Although current diversity initiatives are largely focused on improving the involvement of groups of excluded identities, if they do not foster true inclusion they are unlikely to alter the day-to-day relational sources of discrimination that impact an individual's experience of inclusion (Green and Kalev 2007, Sabharwal 2014). In inclusive environments, individuals of all backgrounds are treated fairly, valued for who they are, and are included in core decision making (Nishii 2013, Sabharwal 2014). This requires that individuals have equal status and an opportunity to get to know each other in more personal ways that allow them to rely less on stereotypes. Academics need the freedom to enact and engage core aspects of their self-concept and/or multiple identities (Kahn 1990, Ramarajan 2009) without suffering unwanted consequences (Ragins 2008). This can be particularly difficult in fields with few individuals from groups of excluded identities, creating an assimilationist environment where nondominant groups must conform to the values and norms of a dominant group.

When ecologists were asked to list the barriers they had to overcome in their careers, 4 of the top 25 barriers were due to leadership (i.e., lack of role models/mentors, support for research goals/interests, institutional support, mentor quality), and 8 of the top 25 barriers were issues of inclusion (i.e., gender issues, cultural support, public support/interest, social issues/activism not valued, teaching not valued, collegiality, applied research not valued; Perkins 2006). With <10% of survey respondents representative of people of excluded identities in ecology (Perkins 2006), inclusion in ecology is a barrier for all, requiring immediate action to evaluate noninclusive behaviors and their impact on performance.

In an era where trust in science has waned, science is more likely to be relevant to society if teachers and researchers reflect the diversity of the broader community (Hayes 2010). As a field, we can do more to empower all young Americans to consider a career in ecology. In addition to traditional venues for sharing research, ecologists must make every effort to inform the public about emerging science. This will require support for social media campaigns that provide content the way the public is receiving information. Academic institutions must also recognize and value individuals that participate in diversity and inclusion programs. Valuing this work will initiate wide participation in diversity programs by all faculty. Real efforts to recruit, train, and nurture all students in ecology must be made at all levels and requires critical mass. All ecologists should feel the responsibility for these efforts and not simply assume that the few minorities in their field can do the majority of the work.

Literature Cited

AlShebli, B. K., T. Rahwan, and W. L. Woon. 2018. The preeminence of ethnic diversity in scientific collaboration. Nature Communications 9:5163.

Applebaum, B. 2019. Remediating campus climate: implicit bias training is not enough. Studies in Philosophy and Education 38:129–141.

Arismendi, I., and B. E. Penaluna. 2016. Examining diversity inequities in fisheries science: a call to action. BioScience 66:584–591.

Bargh, J. A. 1997. The automaticity of everyday life. Pages 1–61 *in*: R. S. Wyer Jr., editor. The automaticity of everyday life: Advances in social cognition. Erlbaum, Hillsdale, New Jersey, USA.

Bargh, J. A. 1999. The cognitive monster: The case against the controllability of automatic stereotype effects. Pages 361–382 *in* S. Chaiken, editor. Dual-process theories in social psychology. Guilford Press, New York, New York, USA.

Bowser, G., and C. R. Cid. 2021. Developing the ecological scientist mindset among underrepresented students in ecology fields. Ecological Applications: e02348. https://doi.org/10.1002/eap.2348

Devine, P. G., and M. J. Monteith. 1999. Automaticity and control in stereotyping. Pages 339–360 *in* S. Chaiken, editor. Dual-process theories in social psychology. Guilford Press, New York, New York, USA.

Ellison, A. M. 2021. Broadening the ecological mindset. Ecological Applications: e02347. https://doi.org/10.1002/eap.2347

Farr, C. M., S. P. Bombaci, T. Gallo, A. M. Mangan, H. L. Riedl, L. T. Stinson, K. Wilkins, D. E. Bennett, T. Nogeire-McRae, and L. Pejchar. 2017. Addressing the gender gap in distinguished speakers at professional ecology conferences. BioScience 67:464–468.

Green, T. K., and A. Kalev. 2007. Discrimination-reducing measures at the relational level. Hastings Law Journal 59:1435.

Hayes, T. B. 2010. Diversifying the biological sciences: past efforts and future challenges. Molecular Biology of the Cell 21:3767–3769.

Hong, L., and S. E. Page. 2004. Groups of diverse problem solvers can outperform groups of high-ability problem solvers. Proceedings of the National Academy of Sciences of the United States of America 101:16385–16389.

Iporac, L. A. R. 2020. Are Asians and Asian-Americans excluded in diversity, equity, and inclusion initiatives? Limnology and Oceanography Bulletin 29:132–133.

Jackson, S. M., A. L. Hillard, and T. R. Schneider. 2014. Using implicit bias training to improve attitudes toward women in STEM. Social Psychology of Education 17:419–438.

Jimenez, M. F., T. M. Laverty, S. P. Bombaci, K. Wilkins, D. E. Bennett, and L. Pejchar. 2019. Underrepresented faculty play a disproportionate role in advancing diversity and inclusion. Nature Ecology & Evolution 3:1030–1033.

Kahn, W. A. 1990. Psychological conditions of personal engagement and disengagement at work. Academy of Management Journal 33:692–724.

Martin, L. J. 2012. Where are the women in ecology? Frontiers in Ecology and the Environment 10:177–178.

Menakem, R. 2017. My grandmother's hands: racialized trauma and the pathway to mending our hearts and bodies. Central Recovery Press, Las Vegas, Nevada, USA.

Monteith, M. J. 1993. Self-regulation of prejudiced responses: Implications for progress in prejudice-reduction efforts. Journal of Personality and Social Psychology 65:469–485.

Monteith, M. J., L. Ashburn-Nardo, C. I. Voils, and A. M. Czopp. 2002. Putting the brakes on prejudice: on the development and operation of cues for control. Journal of Personality and Social Psychology 83:1029–1050.

Monteith, M. J., C. I. Voils, and L. Ashburn-Nardo. 2001. Taking a look underground: detecting, interpreting, and reacting to implicit racial biases. Social Cognition 19:395–417.

Nielsen, M. W., S. Alegria, L. Börjeson, H. Etzkowitz, H. J. Falk-Krzesinski, A. Joshi, E. Leahey, L. Smith-Doerr, A. W. Woolley, and L. Schiebinger. 2017. Opinion: Gender diversity leads to better science. Proceedings of the National Academy of Sciences of the United States of America 114:1740–1742.

Nishii, L. H. 2013. The benefits of climate for inclusion for gender-diverse groups. Academy of Management Journal 56:1754–1774.

Perkins, A. 2006. Profile of ecologists: results of a survey of the membership of the Ecological Society of America. Ecological Society of America. https://www.esa.org/esa/wp-content/uploads/2012/12/profilesReport2006.pdf

Ragins, B. R. 2008. Disclosure disconnects: antecedents and consequences of disclosing invisible stigmas across life domains. AMRO 33:194–215.

Ramarajan, L. 2009. Opening up or shutting down? The effects of multiple identities on problem solving. Harvard Business School Organizational Behavior Unit Working Paper No. 10-041. https://ssrn.com/abstract=1509405 or http://dx.doi.org/https://doi.org/10.2139/ssrn.1509405

Rudman, L. A., R. D. Ashmore, and M. L. Gary. 2001. "Unlearning" automatic biases: The malleability of implicit prejudice and stereotypes. Journal of Personality and Social Psychology 81:856–868.

Sabharwal, M. 2014. Is diversity management sufficient? Organizational inclusion to further performance. Public Personnel Management 43:197–217.

Woolley, A. W., C. F. Chabris, A. Pentland, N. Hashmi, and T. W. Malone. 2010. Evidence for a collective intelligence factor in the performance of human groups. Science 330:686–688.

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Diverse values, philosophies and ideas beget innovation and resilience in ecology and for our world

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Abstract. Intellectual diversity, which is often assessed through social diversity proxies, such as race, ethnicity, and gender, is essential to innovation in ecology. There are many diverse ways of knowing, valuing, and discerning alternatives within ecology and as it is applied to solve global-change issues. However, science is a cultural activity, one that is affected by colonialism, racism, and White supremacy and, like other fields of science, the pursuit of ecological careers has historically been a space of limited opportunities for participation for Black, Indigenous, and People of Color (BIPOC)—narrowing the diverse ways of knowing, valuing, and engaging in ecological work. We seek to debunk the view that such limited participation is a result of BIPOC lacking interest in or proficiency in science, and instead offer that BIPOC communities are places of deep scientific understanding, sociocultural resilience, and cultural wealth. Scientists must broaden their consideration of the ecological sciences and work with BIPOC to establish community-based scientific partnerships that will foster increased ecological career pathways for BIPOC youth.

Key words: BIPOC; climate change; colonialism; global change; indigenous science; intellectual diversity; social diversity; White supremacy.

We approach life and learning through curiosity with the aim of personal leadership, improving understanding of ourselves and the way our actions can support others. We have both been fortunate to engage in learning and to work with practitioners in Communities of Color that include Indigenous Peoples from tribes across the United States and Canada. These experiences have been transformative, leading us towards ever greater appreciation of the wisdom and knowledge that comes from "seeing the world with two eyes," as the braiding of Indigenous and Eurocentric science axiologies and epistemologies has been described by James Rattling Leaf (2021) from the Rosebud Sioux Tribe. From this perspective, our commentary on Bowser and Cid (2021) aims to highlight specific aspects of collaborative learning needed to build a scientific community in which our differences are seen as assets and there are not rites of passage, which we see as barriers. Listening to understand is essential to see how an experience in the field, the classroom, the lab, at a meeting or online may invite someone into the field of ecology or alienate them from it at any career stage.

Each of us has lived different experiences, and through this we have developed particular kinds of diversity; as we consider how diversity might impact the ecological sciences, we need to be explicit about the term "diversity" itself. Yosso (2005) argues that diverse lived experiences provide community cultural wealth in the form of aspirational, familial, social, navigational, resistant, and linguistic capitals that vary across participants. Several types of intellectual diversity that may contribute to different forms of cultural capital have been named, for example, epistemic, axiological, and ontological diversities. For example, multiple scholars have described how epistemic diversity—diverse ways of knowing, reasoning, and engagement in knowledge production practices, supports meaningful and sustainable environmental justice efforts (Emberley 2013, Bang and Vossoughi 2016). Epistemological diversity can help us avoid Type III errors in our research, that is, getting the right answer to the wrong problem, as it influences how we frame research questions — a part of the scientific process that influences the data and impacts of research (Özdemir and Springer 2018). Axiological diversity is seen to spark innovations in "theories, practices, and structures of

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values, ethics, and aesthetics—that is, what is good, right, true, and beautiful—that shape current and possible meaning, meaning-making, positioning, and relations in cultural ecologies" (Bang et al. 2016:28–29). Such diversity is necessary for ecology to consider human–environment interactions in varied ways. Ontological diversity encourages "the invention of new scientific categories, specifically categories that do useful work in generating, selecting among, and assessing design alternatives" (DiSessa and Cobb 2004:78). Different approaches to categorization, among other ontological innovations, have historically helped the field of ecology to advance.

Although these varied forms of intellectual diversity are all essential to fostering innovation within ecology and in society, they are difficult to measure and thus difficult to search for and promote. Therefore, in seeking to include varied intellectual contributions in ecology, we use forms of social diversity—sometimes framed as representational diversity—as proxies, because they are easier to categorize and often reflect varied lived experiences that are thought to be at the root of intellectual diversity. Rodriguez (2016:242) states that

> Diversity involves the recognition of the visible and invisible physical and social characteristics that make an individual or group of individuals different from one another, and by doing so, celebrating that difference as a source of strength for the community at large.

Social diversity proxies are things such as race, ethnicity, gender, socioeconomic status, educational experiences, or the number of languages spoken. Research on diversity in science often focuses on these social diversity proxies; however, the representation of these proxies is not the end goal, but only a means to ensuring intellectual diversity.

Notwithstanding, social diversity proxies do reflect different lived realities that are rooted in historical and current social power differences—experiences often embroiled in oppression. In addition, people experience intersectional issues of oppression that reflect differences in lived experiences within any given social categorization (Collins 2017); for example, Indigenous women and men have widely different lived experiences because of sexism, though they both may experience colonialism. Therefore, social diversity is likely a reasonable proxy for intellectual diversity, as social positionalities reflect widely different lived experiences and histories as people navigate social, institutional, and legal structures that may center them, suppress their advancement, or lead to erasure of their histories. Although innovation in science has been shown to increase with the social diversity of people involved (Freeman and Huang 2015, Mohammadi et al. 2017, AlShebli et al. 2018), it is also important to organize institutional structures to best leverage intellectual diversity of socially diverse team members for innovation (Lambert 2016). Although social diversity should be sought to increase intellectual diversity, it must be sought for ethical reasons; increasing social diversity within ecology career pathways is a way to address the historic exclusion of Black, Indigenous, and People of Color (BIPOC) from these meaningful and important areas of scientific work.

Diversity within Ecology

In considering diversity within ecology, we should also ask ourselves how we are defining the field of ecology itself (Sagarin and Pauchard 2012). Not all ecology is based in Eurocentric teachings or practices. The ecological community has multiple perspectives on how to engage in our shared work (Rattling Leaf 2020). These variations in ecology are rooted in different axiological stances that influence value systems on research (Philip et al. 2018). Our positionality in the world with respect to social diversity influences what we consider as part of this field, as well as how knowledge is acquired and communicated. Our lived experiences are a part of us, influencing the work we do and our commitment to it through our values, beliefs, and practices (Fig. 1). For example, in subsistence communities, immense time is invested to hunt and gather food. Observations of hunters about the presence and abundance of wildlife, of those who fish about currents and changes to the sea, and of gatherers about the relationship between climate and food availability should be seen as equally valid with observations collected by more formal or technological methodologies that are used to assess how patterns today are different than in the past or from place to place. Even more so, the cultural wealth of communities who live in balance with other species represents the central ecological concept of interdependence. There is incredible hubris among ecologists who choose to fly to and across remote regions to assess ecosystem health, while disregarding the knowledge of those who live in balance with the land, water, and species of the region.

Ecological science is more than what has come out of European intellectual histories. Thus, if we frame ecology through only this single understanding—ecologists who are educated in Eurocentric histories of ecology through Eurocentric institutions such as schools—the resulting statistics we collect about who is participating in ecology are flawed. Furthermore, BIPOC are, in particular, often positioned within science as lacking interest in, exposure to, or proficiency with scientific knowledge and practices; however, research indicates that shifting how we frame the work of science and improving the organization of science learning can shift this narrative (Wong 2015, McGee and Bentley 2017). We seek to take an asset perspective to BIPOC as having deep scientific understanding, socioecological resilience, and cultural wealth (Yosso 2005) by centering BIPOC ecologists' work in different ways. For example, UNESCO has started to document climate research and resilience

Fig. 1. Indigenous students innovate and excel in ecology. Left: Hailee McOmber samples soils with Katie Grant near the Rocky Mountain Biological Laboratory, Gothic, Colorado, as part of field collections coordinated with National Ecological Observatory Network's Airborne Observation Platform survey of a mountain watershed. Right: Emily Johnson measures water quality in Hermosa Creek postwildfire, Durango, Colorado. Commitment by faculty and institutions to provide diverse opportunities to learn and demonstrate excellence increases community understanding of each persons' strengths. Photos: H. Steltzer.

within BIPOC communities in their assessment of the assets that frontline communities, those most impacted by climate change, bring into the field of ecological innovations.

If BIPOC have immense scientific understanding and cultural values aligned with ecological concepts, why is this not widely seen? Often, differences in values, philosophies, and ideas are framed as deficits of those lacking privilege and power (Valencia 2012). The way in which educational pathways have been organized does not often allow BIPOC youth to thrive in their own cultural identities, exacerbating achievement gaps as these youth are then measured in ways that again privilege whiteness—something known as educational debt (Ladson-Billings 2006), and further limiting BIPOC pathways into ecology careers. Inferences are then made to explain why such patterns for participation in science degrees, careers, and forums, including global forums to mitigate and adapt to climate change, for example, the Conference of the Parties on Climate Change, exist, as these patterns may result in incomplete narratives. Meanwhile, White scholars working with BIPOC communities who are publishing, become known as experts and are centered in the field, something that needs to be disrupted through citational justice efforts (Mott and Cockayne 2017). Thus, innovative science and impactful science communication are often contributed by BIPOC, though their contributions are often not recognized, nor do they lead to career advancement (Hofstra et al. 2020).

A different framing is needed, beginning with an understanding that scientific activity is cultural in nature (National Research Council [NRC] 2012, National Academies of Sciences, Engineering, and Medicine [NASEM] 2018). We, as scientists, are all positioned within our own cultural norms, values, and beliefs to engage in scientific work in particular ways, often discounting alternative ways that seem foreign to us (Lemke 2001). An example is the perceived rigor of observations that are quantified relative to those that are qualitative, even though the latter can extend over longer time frames and integrate stories to connect people to data (Fondahl and Wilson 2017). The foundations of ecology are rich in description, for example, natural history, and we can return to placing greater value on place-based, descriptive studies. Colonialism, racism, and White supremacy are pervasive globally within the scientific community, as they are in society at large (Delgado and Stefancic 2017). The social consequences of such oppression often constrain BIPOC in the field of ecology, who may feel the need to modify their behaviors in order to participate; such modifications may result in decreased sharing of intellectual diversity that a BIPOC may bring to a science team as a result of ancestral knowledge, cultural interactions, or their values related to human–environment relationships. Furthermore, the masculine contest culture prevalent in work environments, including those in higher education, decreases psychological safety (Berdahl et al. 2018), and often compounds the impacts of racial and cultural differences. Successful recruitment is lost due to low retention of BIPOC faculty across all career stages. Simply put, underrepresentation of BIPOC in ecology and other environmental science fields, such as the geosciences (Bernard and Copperdock 2018), is about White supremacy, the immense inequities it creates and, at times, the insurmountable hurdles it erects. Although there is abundant research on this, we have both also witnessed this personally.

Understanding and Fostering the Contributions of BIPOC Scientists and Communities

> In a canvas wall tent set up on a braided river in Northwestern Alaska, I would sit for hours manually titrating water samples to record their alkalinity. It was the year 2000, and Heidi was a newly minted PhD eager to characterize ecological changes in the Arctic. Wind would whip the tent's walls. Bears would nose by. And I would listen to KOTZ public radio out of Kotzebue. The community had organized a forum to discuss the mining of lead at Red Dog Mine, and the forum was broadcast.
>
> Amidst talk by politicians, representatives from government agencies and mining executives, Indigenous elders clearly stated their concerns—they did not want new data or assurances of little harm. They "knew" that mining and transporting ever more lead from the tundra would impact plants, animals, and their community's well-being. Their concerns were founded on centuries of observation and intuition, as well as their values. They urged precaution, recommending the mining company and government act in the best interest of future generations.

Heavy metals biomagnify in food chains such that bits of lead, yes, even dust, can cause health issues for higher-level consumers. Precaution is an established concept in Eurocentric science, as it is in many scientific communities, in order to protect vulnerable groups and the population as a whole (Foster et al. 2000). However, despite this scientific knowledge provided by the elders, or that could have been contributed by scientists, lead mining would continue without sufficient precaution in an Indigenous community where many hunt, fish, and gather their food. In systems of oppression, knowledge is not power. Heidi Steltzer understood the injustice. Those who knew the land best could not protect it.

Furthermore, rigorous quantification of the changing Arctic, its loss of ice and snow (Meredith et al., *in press*), its burning and thawing land (Holloway et al. 2020), and the accumulating pollution (Sonne et al. 2017), has not yet led to policies that protect people and place. Ecology is at the center of many global change issues, including climate change (Fig. 2) and the COVID-19 pandemic. To increase the impact of ecology in solving such issues, the credentialed ecological community—those with power and privilege, often with graduate degrees in science—must engage more diverse values, philosophies, and ideas than it has in the past. For example, this can be done by recognizing and funding the work of ecologists who effectively share science through narrative, are human-encouraging rather than competitive, and listen to understand. These scientists not only expand ecological practices but also seek to mentor the credentialing of those in BIPOC communities who then shift the field of ecology in impactful ways. Through these practices, the field of ecology itself will increase its resilience to sociocultural and environmental changes.

Although much has been done to document and lift the voices of Indigenous scientists and shift inequitable power dynamics present in such situations (e.g., Krupnik

Fig. 2. Ecology is central to diplomacy to mitigate and adapt to global changes from climate change to Arctic pollution to pandemics (Mauduit and Gual Soler 2020). Intellectual diversity is essential to create the vision and ensure enduring actions result from global forums, such as COP25. Inequities in being heard persist as a consequence of racism and colonialism in the educational systems through which individuals become credentialed scientists. Image: ricochet64 via Shutterstock.

and Jolly 2002, Barnhardt and Oscar Kawagley 2005, Whitt 2009), inequities both in being heard, understood, and at the table to make decisions about everyday life and community well-being persist. Some of this is a result of the status given to “credentialed scientists” (i.e., those with Ph.D.s) without a deeper exploration of how education itself is a colonial space, rife with racism and inequity (Harding 2006, Medin and Bang 2014, Mensah 2019).

As an example, summer field programs in ecology that recruit BIPOC students often provide an application process that they need support to complete. Hurdles may include the individualism characteristic of Eurocentric norms or requests for letters of recommendation. BIPOC students may see themselves as scientists, but may have been told they do not picture themselves as scientists, and thus question what to state for career aims. Their answers may be doubted if they are true to themselves. Additionally, the process often rewards students who have adapted to Eurocentric practices rather than those who choose to demonstrate sociocultural resilience and cultural wealth. Rolling applications or individualized guidance from programs seeking diverse students may allow more opportunities for those not familiar with the bureaucracy of higher educational institutions or the discourse privileged in application processes. Changing the process for application submission and review can increase participation of BIPOC by removing structural exclusionary practices limiting access to STEM opportunities in higher education (Dutt 2019, McGee 2020).

Faculty who teach at BIPOC-serving institutions do not have sufficient time to guide every student who needs support through the application process, nor can they compel a student to fit the niche offered by a program. Instead, it is time to ask that programs change rather than that students change, and for more of these programs to be offered in BIPOC communities and at the institutions they attend. There are critical points within the career pathways of BIPOC youth that require thoughtful, structural supports to be enacted across multiple institutions, and it is critical that all ecology faculty are working to support such innovations to foster diversity in the field (Fealing et al. 2015, Packard 2015). There are different learning pathways that can be offered and credentialed, if this remains important (e.g., Roth et al. 2019). Such innovations could include centering educational choices in the hands of BIPOC students to select their own mentors across university and early career science contexts, by providing the students with the funds for research or training experiences. Structural supports for BIPOC ecology pathways should ensure that there are multiple points of support across both school- and community-based learning contexts and that a wide range of mentors is available to foster resilience while at the same time ensuring that all scientists learn to desettle inequity (Banks et al. 2007, Bang et al. 2012).

Designing for Diversity in Ecology

> The sun is just starting to peek over the eastern skyline as we quietly walk backwards into the cool waters of the Salish Sea. It is February, so it is brisk. We are part of a community-based science learning partnership between the WSANEC First Nation and the Pender Island communities called TETACES Climate Action Project. We slowly swish cedar over our bodies as we submerge ourselves three times before letting the cedar float out into the ocean as we exit the water.
>
> We are now ready to greet the day well intentioned without negativity and with a deep sense of our responsibilities to place. We are seeking to find ways to center indigeneity in science learning while weaving together different science knowledges and practices. Deb takes a deep breath as she thinks about how this clarity of responsibility feels necessary to ensure we struggle with whiteness in our work towards justice, ensuring that we are humble, listen deeply, ensure we authentically seek reciprocity and reconciliation, and work to foster climate resilience for all.

Scientists and science educators need to commit to challenging their own understandings of how learning environments and activities are either disrupting colonialism, racism, and anti-Blackness, or reproducing oppressive experiences for BIPOC learners. In science educational settings, the work of equity and justice means many things. Community-based science learning partnerships illustrates the way that being in relation to place, to the cultures of this place, and the responsibilities as part of this socioecological system is woven into the activity of learning and being together as scientists and educators. It includes structuring ways to listen and connect to those with whom you work while at the same time expanding the diversity of those you mentor, collaborate with, and learn from. Higher education and research should include resources and examples to ensure that BIPOC assets and histories are brought into conversation with other aspects of scientific knowledge and practices. Reading into and experiencing different cultural science communities is a first step (Fienup-Riordan 2007). Critical conversations that broaden our awareness of our own biases and prejudices are also essential so long as they lead to structural changes in the ways we do our work (Schell et al. 2020, Tseng et al. 2020). These are conversations in which people can reflect, while others listen and ask questions to guide us to think more deeply about our views of science and its culture.

Expanding community science partnership work from expanding stances of justice that result from personal learning and justice are also critical to transforming BIPOC participation in ecology (Bettez and Hytten

2013, Bang et al. 2016). Field programs and stations still rarely exist in BIPOC communities; yet, for many youth from these communities who attend colleges away from home, returning to their communities, acquiring internships, and pursuing ecology careers are priorities. For ecology careers to be pursued by BIPOC, people who often lack power and are being harmed to a greater extent as a consequence of environmental changes (Gardiner 2020, Johnson 2020), (1) ecological insights must be valued by those with power to protect human well-being and (2) field experiences should take place in and aim to inform actions to protect Communities of Color. These design principles reflect the ideas of relationality —the idea that we all work in relation to each other, to the contexts in which we work, and to the places in which we live (Lange 2018). Ideas of relationality also help us think about learning from and with the environment in ways that resonate for many ecologists (Muller et al. 2019, Pugh et al. 2019). In the field of ecology, we already value genetic, species, and ecosystem diversity, and have demonstrated that this diversity increases ecological stability and resilience (Tilman and Downing 1994, Hooper et al. 2005). In the work of ecology, we need to also value epistemic, axiological, and ontological diversity that is rich in BIPOC communities.

Creating space for BIPOC scientists and youth in the Ecological Society of America will allow our organization to become a thriving, diverse socioecological community that is resilient to sociocultural and environmental changes. Such efforts support our essential role in society to foster more just and long-term solutions as our environment radically changes. Going forward we need to learn a different way of being and doing within science—a way that is deeply connected to people and the well-being of all.

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Literature Cited

AlShebli, B. K., T. Rahwan, and W. L. Woon. 2018. The preeminence of ethnic diversity in scientific collaboration. Nature Communications 9:5163. https://doi.org/10.1038/s41467-018-07634-8.

Bang, M., L. Faber, J. Gurneau, A. Marin, and C. Soto. 2016. Community-based design research: Learning across generations and strategic transformations of institutional relations toward axiological innovations. Mind, Culture, and Activity 23:28–41.

Bang, M., and S. Vossoughi. 2016. Participatory design research and educational justice: Studying learning and relations within social change making. Cognition and Instruction 34:173–193.

Bang, M., B. Warren, A. S. Rosebery, and D. Medin. 2012. Desettling expectations in science education. Human Development 55:302–318.

Banks, J., et al. 2007. Learning in and out of school in diverse environments: Life-long, life-wide, life-deep. The LIFE Center (University of Washington, Stanford University and SRI) & the Center for Multicultural Education, University of Washington, Seattle, Washington, USA.

Barnhardt, R., and A. O. Kawagley. 2005. Indigenous knowledge systems and Alaska Native ways of knowing. Anthropology & Education Quarterly 36:8–23.

Berdahl, J. L., M. Cooper, P. Glick, R. W. Livingston, and J. C. Williams. 2018. Work as a masculinity contest. Journal of Social Issues 74:422–448.

Bernard, R. E., and E. H. G. Cooperdock. 2018. No progress on diversity in 40 years. Nature Geoscience 11:292–295.

Bettez, S. C., and K. Hytten. 2013. Community building in social justice work: a critical approach. Educational Studies 49:45–66.

Bowser, G., and C. R. Cid. 2021. Developing the ecological scientist mindset among underrepresented students in ecology fields. Ecological Applications: e02348. https://doi.org/10.1002/eap.2348

Collins, P. H. 2017. On violence, intersectionality and transversal politics. Ethnic and Racial Studies 40:1460–1473.

Delgado, R., and J. Stefancic. 2017. Critical race theory: An introduction. Volume 20. NYU Press, New York, New York, USA.

DiSessa, A. A., and P. Cobb. 2004. Ontological innovation and the role of theory in design experiments. Journal of the Learning Sciences 13:77–103.

Dutt, K. 2019. Promoting racial diversity in geoscience through transparency. Eos 100. https://doi.org/10.1029/2019EO136977.

Emberley, J. 2013. Epistemic heterogeneity: Indigenous storytelling, testimonial practices, and the question of violence in Indian residential schools. Pages 143–158 *in* J. Henderson and P. Wakeman, editors. Reconciling Canada: Critical perspectives on the culture of redress. University of Toronto Press, Toronto, Ontario, Canada.

Fealing, K. H., Y. Lai, and S. L. Myers, Jr. 2015. Pathways vs. pipelines to broadening participation in the STEM workforce. Journal of Women and Minorities in Science and Engineering 21:271–293.

Fienup-Riordan, A. 2007. Yuungnaqpiallerput/the way we genuinely live: Masterworks of Yup'ik science and survival. University of Washington Press, Seattle, Washington, USA.

Fondahl, G., and G. N. Wilson, editors. 2017. Northern sustainabilities: understanding and addressing change in the circumpolar world. Springer, Berlin, Germany.

Foster, K. R., P. Vecchia, and M. H. Repacholi. 2000. Science and the precautionary principle. Science 288:979–981.

Freeman, R. B., and W. Huang. 2015. Collaborating with people like me: Ethnic coauthorship within the United States. Journal of Labor Economics 33:S289–S318.

Gardiner, B. 2020. Unequal impact: The deep links between racism and climate change. Yale Environment 360. https://e360.yale.edu/features/unequal-impact-the-deep-links-between-inequality-and-climate-change

Harding, S. 2006. Science and social inequality: Feminist and postcolonial issues. University of Illinois Press, Champaign, Illinois, USA.

Hofstra, B., V. V. Kulkarni, S. M. N. Galvez, B. He, D. Jurafsky, and D. A. McFarland. 2020. The diversity–innovation paradox in science. Proceedings of the National Academy of Sciences of the United States of America 117:9284–9291.

Holloway, J. E., A. G. Lewkowicz, T. A. Douglas, X. Li, M. R. Turetsky, J. L. Baltzer, and H. Jin. 2020. Impact of wildfire on permafrost landscapes: A review of recent advances and future prospects. Permafrost and Periglacial Processes 31:371–382.

Hooper, D. U., et al. 2005. Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. Ecological Monographs 75:3–35.

Johnson, A. J. 2020. I'm a black climate expert. Racism derails our efforts to save the planet. Washington Post, Washington, D.C., USA.

Krupnik, I., and D. Jolly. 2002. The earth is faster now: indigenous observations of arctic environmental change. *In* Frontiers in polar social science. Arctic Research Consortium of the United States, Fairbanks, Alaska, USA.

Ladson-Billings, G. 2006. From the achievement gap to the education debt: Understanding achievement in US schools. Educational Researcher 35:3–12.

Lambert, J. 2016. Cultural diversity as a mechanism for innovation: Workplace diversity and the absorptive capacity framework. Journal of Organizational Culture, Communications and Conflict 20:68.

Lange, E. A. 2018. Transforming transformative education through ontologies of relationality. Journal of Transformative Education 16:280–301.

Lemke, J. L. 2001. Articulating communities: Sociocultural perspectives on science education. Journal of Research in Science Teaching 38:296–316.

Mauduit, J.-C., and M. Gual Soler. 2020. Building a science diplomacy curriculum. Frontiers in Education 5:138.

McGee, E. O. 2020. Interrogating structural racism in STEM higher education. Educational Researcher 49:633–644.

McGee, E., and L. Bentley. 2017. The equity ethic: Black and Latinx college students reengineering their STEM careers toward justice. American Journal of Education 124:1–36.

Medin, D. L., and M. Bang. 2014. Who's asking?: Native science, western science, and science education. MIT Press, Cambridge, Massachusetts, USA.

Mensah, F. M. 2019. Finding voice and passion: Critical race theory methodology in science teacher education. American Educational Research Journal 56:1412–1456.

Meredith, M., et al. 2019. Polar regions. Chapter 3, IPCC Special Report on the Ocean and Cryosphere in a Changing Climate.

Mohammadi, A., A. Broström, and C. Franzoni. 2017. Workforce composition and innovation: how diversity in employees' ethnic and educational backgrounds facilitates firm-level innovativeness. Journal of Product Innovation Management 34:406–426.

Mott, C., and D. Cockayne. 2017. Citation matters: mobilizing the politics of citation toward a practice of "conscientious engagement." Gender, Place & Culture 24:954–973.

Muller, S., S. Hemming, and D. Rigney. 2019. Indigenous sovereignties: relational ontologies and environmental management. Geographical Research 57:399–410.

National Academies of Sciences, Engineering, and Medicine. 2018. Learning through citizen science: enhancing opportunities by design. National Academies Press, Washington, D.C., USA.

National Research Council. 2012. A framework for K-12 science education: Practices, crosscutting concepts, and core ideas. National Academies Press, Washington, D.C., USA.

Özdemir, V., and S. Springer. 2018. What does "diversity" mean for public engagement in science? A new metric for innovation ecosystem diversity. OMICS: A Journal of Integrative Biology 22:184–189.

Packard, B. W. L. 2015. Successful STEM mentoring initiatives for underrepresented students: A research-based guide for faculty and administrators. Stylus Publishing LLC, Sterling, Virginia, USA.

Philip, T. M., M. Bang, and K. Jackson. 2018. Articulating the "how," the "for what," the "for whom," and the "with whom" in concert: a call to broaden the benchmarks of our scholarship. Cognition and Instruction 36:83–88.

Pugh, P., M. McGinty, and M. Bang. 2019. Relational epistemologies in land-based learning environments: reasoning about ecological systems and spatial indexing in motion. Cultural Studies of Science Education 14:425–448.

Rattling Leaf, J. 2020. The decade of traditional knowledge: Opportunities to build greater understanding between the western scientific and traditional knowledge paradigm. In 2020 ESA Annual Meeting (August 3-6). ESA.

Rattling Leaf, J. 2021. Guest speaker on the current landscape of climate change education at the first Climate Change Education Collective meeting, held virtually, January 7, 2021. https://ccecollective.org/conference/

Rodriguez, A. J. 2016. For whom do we do equity and social justice work? Recasting the discourse about the other to effect transformative change. Pages 241–252 *in* N. M. Joseph, C. M. Haynes, and F. Cobb, editors. Interrogating whiteness and relinquishing power: White faculty's commitment to racial consciousness in STEM classrooms. Peter Lang, New York, New York, USA.

Roth, W. M., M. Van Eijck, G. Reis, and P. L. Hsu. 2019. Authentic science revisited: In praise of diversity, heterogeneity, hybridity. Brill Sense, Leiden, Netherlands.

Sagarin, R., and A. Pauchard. 2012. Observation and ecology: broadening the scope of science to understand a complex world. Island Press, Washington, D.C., USA. https://doi.org/10.5822/978-1-61091-230-3

Schell, C. J., C. Guy, D. S. Shelton, S. C. Campbell-Staton, B. A. Sealey, D. N. Lee, and N. C. Harris. 2020. Recreating Wakanda by promoting Black excellence in ecology and evolution. Nature Ecology & Evolution 4:1285–1287.

Sonne, C., et al. 2017. A veterinary perspective on One Health in the Arctic. Acta Veterinaria Scandinavica 59:84. https://doi.org/10.1186/s13028-017-0353-5.

Tilman, D., and J. A. Downing. 1994. Biodiversity and stability in grasslands. Nature 367:363–365.

Tseng, M., R. W. El-Sabaawi, M. B. Kantar, J. H. Pantel, D. S. Srivastava, and J. L. Ware. 2020. Strategies and support for Black, Indigenous, and people of colour in ecology and evolutionary biology. Nature Ecology & Evolution 4:1288–1290.

Valencia, R. R. (Ed.). 2012. The evolution of deficit thinking: Educational thought and practice. Routledge, London, UK.

Whitt, L. 2009. Science, colonialism, and indigenous peoples: The cultural politics of law and knowledge. Cambridge University Press, Cambridge, UK.

Wong, B. 2015. Careers "from" but not "in" science: Why are aspirations to be a scientist challenging for minority ethnic students? Journal of Research in Science Teaching 52:979–1002.

Yosso, T. J. 2005. Whose culture has capital? A critical race theory discussion of community cultural wealth. Race Ethnicity and Education 8:69–91.

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The identity crisis of ecological diversity

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Abstract. *Developing the ecological scientist mindset among underrepresented students in ecology fields* (Bowser and Cid, this Forum) provides timely and compelling strategies to broaden inclusion in ecology and environmental biology. Chronic underrepresentation of minorities in ecology and environmental disciplines (EE) is a crisis that is surprising to many, and even more surprising that, for African-Americans, this underrepresentation is more severe compared to other STEM disciplines. It is beyond irony that a discipline that values diversity as a cornerstone of ecological practice continues to struggle to achieve diversity in the ranks of its practitioners.

Key words: *culture; deficit model; diverse knowledge; inclusion; retention; structural inequity.*

. . .I must be the bridge to nowhere
But my true self
And then
I will be useful

—excerpt from The Bridge Poem by Kate Rushin

Bowser and Cid's (2021) intervention centers on cultivating an ecological mindset, or identity as an ecologist. Broadly speaking, a scientific identity influences STEM persistence for K–12 students (e.g., Sparks and Pole 2019) and college-level students (Bowser and Cid, 2021). This identity is more easily obtained among dominant culture students, but frequently must be nurtured for underrepresented minorities (Gazley et al. 2014, Estrada et al. 2016). Within any given research area, scientific identity has as much to do with disciplinary emphasis and academic preparation as with the cultural lens of those whose experiences are included and excluded in predominant disciplinary narratives (Dodson et al. 2009, Miriti 2019, Kanim and Cid 2020). As a result, improving diverse participation in ecology and environmental disciplines (EE) requires examination of the structural and institutional cultures that inform EE identities and disciplinary values.

Ecology and the environment are frequently associated with white culture (Stapleton 2019) to the detriment of diverse participation. Surveys of the Ecological Society of America support this association by showing that the typical ecologist is a middle-aged, white male (Lockwood et al. 2013) who is disengaged with social responsibility (Reiners et al. 2013). This identity, most frequently encountered by students in the classroom, and in EE textbooks (Damschen et al. 2005), undermines diversity initiatives because positive scientific identities among students in racially homogeneous environments, such as those found in EE (O'Brien et al., 2020), are supported for white, but not minority students (Wout et al. 2010). Underrepresented students and professionals in EE who persist may experience an insidious and personally taxing desire to assimilate to gain credibility (Bergstrom 2019, Spikes 2020). Bergstrom (2019) shows that the predominance of white, male, science identities is associated with attrition of underrepresented minorities from undergraduate through full professor ranks. This relationship underscores the fact that, as in other STEM disciplines, retention, not recruitment, of underrepresented and historically marginalized groups is a critical, but often overlooked component of fostering increased diversity and inclusion.

Focusing on retention shifts the emphasis away from recruitment initiatives that employ coursework interventions, primarily math, to retain students in a STEM "pipeline." Although these interventions can diversify the students who enter EE programs (Flowers et al. 2016), low student retention is reflected in the chronic

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lack of diversity in all EE ranks. Pipeline interventions at their worst provide a misleading metaphor for STEM success. According to Cannady et al. (2014), while in high school, 61% of scientists had no interest in STEM, or had no calculus, and 16% had neither. Along a similar vein, Armstrong et al. (2007) suggest that students who gain interest in EE will seek out necessary skills and research experiences, but a lack of positive, validating experiences in EE reduces retention. These findings underscore the insufficiency of deficit models that attempt to increase diversity by providing academic skills that students lack. Consideration of cultural biases in EE practice and education provides an alternative pathway to assess student success (e.g., Miriti 2019). Improving cultural and social barriers can retain diversity in EE and cultivate positive identities among underrepresented minorities.

As with any other identity, the ecological identity includes a social context that is either supportive or corrosive. To cultivate a positive ecological identity broadly and promote diverse participation, we must accept that science is not produced in a cultural/racial/value-free vacuum (Longino 1990, Pulido 2002): knowledge and culture are co-produced.

The relationship between racialized, dominant culture values and disciplinary values is acknowledged in other academic disciplines (Harris and González 2012, Tolia-Kelly 2017), but has been under-examined or discounted in STEM (Vakil and Ayers 2019), although Graves (2019) presents a recent examination for evolutionary biology. The influence of race on scientific practice is rarely presented in STEM journals (but see Miriti 2020); however, in response to the undeniable racial disparity in COVID-19 occurrence and mortality, the time to confront structural racism in STEM is overdue.[2,3]

Racial biases are evident in institutional and disciplinary practices, which are disproportionately informed by the values of white culture and underlie a low sense of belonging at all academic ranks (Estrada et al. 2016, McGee 2016, Bergstrom 2019, Miriti 2019). In other words, racialized value systems discourage retention of underrepresented students, and reduce retention and promotion of underrepresented faculty (Whittaker et al. 2015, see Schell et al. 2020 for an example focusing on EE). A Ph.D. does not render faculty of color immune to the microagressions that stem from racism or racial blindness (Harris and González 2012, Ross and Edwards 2016, Graves 2019), whether they originate from colleagues and/or students, and in fact can be experienced more frequently by faculty than students (Brown et al. 2016). To avoid a positive feedback loop in which low retention of faculty of color translates to low diversity among students (e.g., McGee 2016), institutional, racial, and cultural barriers must be dismantled.

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By advocating that mentors build on the strengths and experiences of diverse students, Bowser and Cid (2021) provide a culturally sensitive path to nurture an EE identity and improve EE diversity. This path intentionally reduces racialized biases within EE education and practice. The ability to "meet students where they are" is inherent to culturally sensitive pedagogies (Lee et al. 2017, Dewsbury and Brame 2019, Dewsbury 2020) and participatory strategies (Roth and Lee 2004, Nadkarni et al. 2019) that are gaining traction in education and outreach. Such strategies foster a safe space for students to share experiences that are not included in dominant, disciplinary narratives. Because lived experiences are integral to knowledge production, storytelling is a powerful tool for change (Delgado 1989, DeCuir-Gunby et al. 2009, Mizelle 2019). Acceptance of counter-narratives that present minority experiences and perspectives can improve educational outcomes (Solórzano and Yosso 2002), allow underrepresented minorities to contribute with an authentic voice, and promote deserved recognition of the contributions of underrepresented minorities to ecology and environmental biology (Lee 2020, Miriti et al. 2020). The latter encourages a more favorable positive feedback that is recently being asserted by scholars of color from historic and forward looking perspectives (Graves 2019, Lee 2020, Miriti et al. 2020, Schell et al. 2020): greater visibility of scholars of color promotes greater disciplinary diversity, which in turn reinforces the scientific identities of underrepresented students.

In conclusion, increasing participation in ecology and environmental biology requires embracing the cultural identities of underrepresented minorities. This practice permits authentic expression of diverse knowledge that benefits all. Diversity among EE practitioners, like biodiversity in nature, improves community performance and resilience. Like biodiversity, diversity among practitioners must be nurtured as protection against human choices that threaten its existence.

Literature Cited

Armstrong, M. J., A. R. Berkowitz, L. A. Dyer, and J. Taylor. 2007. Understanding why underrepresented students pursue ecology careers: a preliminary case study. Frontiers in Ecology and the Environment 5:415–420.

Bergstrom, R. A. 2019. Motion sickness as metaphor: engaging with diversity in STEM. Advances in Physiology Education 43:1–6.

Bowser, G., and C. Cid. 2021. Developing the ecological scientist mindset among underrepresented students in ecology fields. Ecological Applications: e02348. https://doi.org/10.1002/eap.2348

Brown, B. A., J. B. Henderson, S. Gray, B. Donovan, S. Sullivan, A. Patterson, and W. Waggstaff. 2016. From description to explanation: an empirical exploration of the African-American pipeline problem in STEM. Journal of Research in Science Teaching 53:146–177.

Cannady, M. A., E. Greenwald, and K. N. Harris. 2014. Problematizing the STEM pipeline metaphor: Is the STEM pipeline metaphor serving our students and the STEM workforce? Science Education 98:443–460.

Damschen, E. I., K. M. Rosenfeld, M. Wyer, D. Murphy-Medley, T. R. Wentworth, and N. M. Haddad. 2005. Visibility matters: Increasing knowledge of women's contributions to ecology. Frontiers in Ecology and the Environment 3:212–219.

DeCuir-Gunby, J. T., L. A. Long-Mitchell, and C. Grant. 2009. The emotionality of women professors of color in engineering: a critical race theory and critical race feminism perspective. Pages 323–342 *in* P. A. Schutz and M. Zembylas, editors. Advances in teacher emotion research: the impact on teachers' lives. First edition. Springer US, New York, NY, USA.

Delgado, R. 1989. Storytelling for oppositionists and others: A plea for narrative. Michigan Law Review 87:2411–2441.

Dewsbury, B. M. 2020. Deep teaching in a college STEM classroom. Cultural Studies of Science Education 15:169–191.

Dewsbury, B., and C. J. Brame. 2019. Inclusive teaching. CBE Life Sciences Education 18:1–5.

Dodson, J. E., B. L. Montgomery, and L. J. Brown. 2009. "Take the Fifth": Mentoring students whose cultural communities were not historically structured into U.S. higher education. Innovative Higher Education 34:185–199.

Estrada, M., et al. 2016. Improving underrepresented minority student persistence in STEM. CBE Life Sciences Education 15:1–10.

Flowers, S. K., K. M. Beyer, E. Visions, A. Avenue, and S. Louis. 2016. Early entry into ecology: Authentic field research experiences for high school youth. Bulletin of the Ecological Society of America 97:111–122.

Gazley, J. L., R. Remich, M. E. Naffziger-Hirsch, J. Keller, P. B. Campbell, and R. McGee. 2014. Beyond preparation: Identity, cultural capital, and readiness for graduate school in the biomedical sciences. Journal of Research in Science Teaching 51:1021–1048.

Graves, J. L. 2019. African Americans in evolutionary science: Where we have been, and what's next. Evolution: Education and Outreach 12:1–10.

Harris, A. P., and C. G. González. 2012. Introduction. Pages 1–14 *in* G. Gutiérrez y Muhs, Y. F. Niemann, C. G. González, and A. P. Harris, editors. Presumed incompetent: the intersections of race and class for women in academia. First edition. Utah State University Press, Logan, UT, USA.

Kanim, S., and X. C. Cid. 2020. Demographics of physics education research. Physical Review Physics Education Research 16:1–17.

Lee, A., R. Poch, M. K. O'Brien, and C. Solheim. 2017. Teaching interculturally. Stylus Publishing, Sterling, Virginia, USA.

Lee, D. N. 2020. Diversity and inclusion activisms in animal behaviour and the ABS: a historical view from the U.S.A. Animal Behaviour 164:273–280.

Lockwood, J. A., D. S. Reiners, and W. A. Reiners. 2013. The future of ecology: A collision of expectations and desires? Frontiers in Ecology and the Environment 11:188–193.

Longino, H. E. 1990. Science as social knowledge. Princeton University Press, Princeton, New Jersey, USA.

McGee, E. O. 2016. Devalued Black and Latino Racial Identities. American Educational Research Journal 53:1626–1662.

Miriti, M. N. 2019. Nature in the eye of the beholder: A case study for cultural humility as a strategy to broaden participation in STEM. Education Sciences 9:291. https://doi.org/10.3390/educsci9040291

Miriti, M. N. 2020. The elephant in the room: race and STEM diversity. BioScience 70:237–242.

Miriti, M. N., K. Bailey, S. J. Halsey, and N. C. Harris. 2020. Hidden figures in ecology and evolution. Nature Ecology & Evolution 4:1282. https://doi.org/10.1038/s41559-020-1270-y

Mizelle, R. M. 2019. Race and environmental history. History Compass 17:e12527.

Nadkarni, N. M., C. Q. Weber, S. V. Goldman, D. L. Schatz, S. Allen, and R. Menlove. 2019. Beyond the deficit model: The ambassador approach to public engagement. BioScience 69:305–313.

O'Brien, L. T., H. L. Bart, and D. M. Garcia. 2020. Why are there so few ethnic minorities in ecology and evolutionary biology? Challenges to inclusion and the role of sense of belonging. Social Psychology of Education 23:449–477.

Pulido, L. 2002. Reflections on a white discipline. Professional Geographer 54:42–49.

Reiners, W. A., D. S. Reiners, and J. A. Lockwood. 2013. Traits of a good ecologist: What do ecologists think? Ecosphere 4:86. https://doi.org/10.1890/ES13-00025.1

Ross, H. H., and W. J. Edwards. 2016. African American faculty expressing concerns: breaking the silence at predominantly white research oriented universities. Race Ethnicity and Education 19:461–479.

Roth, W. M., and S. Lee. 2004. Science education as/for participation in the community. Science Education 88:263–291.

Schell, C. J., C. Guy, D. S. Shelton, S. C. Campbell-Staton, B. A. Sealey, D. N. Lee, and N. C. Harris. 2020. Recreating Wakanda by promoting Black excellence in ecology and evolution. Nature Ecology & Evolution 4:1285–1287.

Solórzano, D. G., and T. J. Yosso. 2002. Critical race methodology: Counter-storytelling as an analytical framework for education research. Quantitative Inquiry 8:23–44.

Sparks, D. M., and K. Pole. 2019. "Do we teach subjects or students?" Analyzing science and mathematics teacher conversations about issues of equity in the classroom. School Science and Mathematics 119:405–416.

Spikes, M. 2020. The pressure to assimilate. Science 368:1506.

Stapleton, S. R. 2019. Toward critical environmental education: a standpoint analysis of race in the American environmental context. Environmental Education Research 4622:1–16.

Tolia-Kelly, D. P. 2017. A day in the life of a geographer: 'lone'1, black, female. Area 49:324–328.

Vakil, S., and R. Ayers. 2019. The racial politics of STEM education in the USA: interrogations and explorations. Race Ethnicity and Education 22:449–458.

Whittaker, J. A., B. L. Montgomery, and V. G. Martinez Acosta. 2015. Retention of underrepresented minority faculty: Strategic initiatives for institutional value proposition based on perspectives from a range of academic institutions. Journal of Undergraduate Neuroscience Education 13:A136–A145.

Wout, D. A., M. C. Murphy, and C. M. Steele. 2010. When your friends matter: The effect of White students' racial friendship networks on meta-perceptions and perceived identity contingencies. Journal of Experimental Social Psychology 46:1035–1041.

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The (un)discovering of ecology by Alaska Native ecologists

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Abstract. When do Native students discover ecology and what factors contribute to the low enrollment of diverse students? Addressing such questions is crucial for diversifying science disciplines and the workforce of ecology and geoscience disciplines. Field sciences such as ecology have notably low enrollment of students from underrepresented groups, such as Black/African American, Hispanic/Latinx, and Native American or Alaska Natives. Here we discuss the factors that affect Native students and provide strategies to improve recruitment and retention of Native students in the sciences.

Key words: *diversity; ecological mentoring; historical knowledge; Native ecology; traditional ecological knowledge.*

Discovering Ecology in Native American Communities

The question posited "How do people discover ecology?" by Bowser and Cid (2021) and their acknowledgment that understanding this question is vital to diversifying not only ecology but all science disciplines and thus the environmental workforce allows the field an opportunity to gain a better understanding of the richness of various ecological knowledge systems within communities of color.

Contemplation of this question leads to the realization that the notion of discovering ecology by Alaska Native people, of which many live a cultural and traditional use (e.g., subsistence) lifestyle, is foreign as the concepts of ecology and other disciplines, often compartmentalized in academia, are part of our everyday life. Alaska Native youth are taught traditional ways of knowing from an early age, and are taught to consider all things in a holistic way where all is connected. This is reflected in our understanding that we are part of the ecosystem in which we live, intimately connected with a relationship with the environment. For example, Alaska Natives acknowledge the beinghood of all things and maintain that respect should be given to even the smallest grain of sand. The relationality we have with all things, such as the environment and the ecosystems it supports, requires that we coexist in a balanced and equitable means in which we give the same as what we take. This is in stark contrast to mainstream societies disconnect where one is merely an inhabitant, occupying space but separate from the environment in which they live in and impact, where the environment is a commodity. Traditional Knowledge systems and ways of knowing have the ability to contribute to ecological understanding in a meaningful way if only the field would engage with cultural practitioners and Native scholars when considering research questions, allowing for an exchange of cross-cultural knowledge and by recognizing that there are multiple ways of seeing and interacting with the environment and ecosystems.

In some Alaska Native communities, youth as young as eight years old hunt, fish, and harvest a variety of plants from the land and water to provide for their families, as there are few stores to buy food. These young ones are taught about ecology, geoscience, and ocean science in addition to historical environmental, cultural connections and climate impacts on local and regional ecosystems. They are taught to respect the environment, to take only what is needed as not to negatively impact ecosystems that have sustained Alaska Native communities for hundreds to thousands of years. Ecological knowledge is shared through art, place-based active learning, and oral traditions passed on by family members (Fig. 1). This form of ecology is holistic, encompassing emotional, spiritual, intellectual, social, and physical concepts in a single idea. In this context, ecology is a way of life, a

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concept understood and utilized every day. From this understanding of how Native communities rely on ecological understanding one would think that there would be more Native American or Alaska Native ecologists. However, within the United States, there is a notable lack of diversity in Science Technology Engineering and Math (STEM) disciplines, with less than 30% of science and engineering fields comprised of underrepresented racial groups (e.g., Native Americans and Alaska Natives, Black/African American, Hispanic, Latinx, etc.; NSB 2020). Within the field of ecology, the lack of diversity is staggeringly low considering the connection that many Indigenous groups (e.g., Native American, Alaska Native, Pacific Islander, Hispanic, Black/African American) have with their environment. A survey of membership within the Ecological Society of America (ESA) in 1993 and 2014 revealed that only 9% of memberships were held by racially diverse ecologists (Beck et al. 2014). In 2018, of Ph.D.s conferred in ecology, 85% were awarded to white students, and collectively 7.55% were conferred to Native American/Alaska Native (0%), Black/African American (0%), and Hispanic (7.55%) students (e.g., Lawrence et al. 1993; Beck et al. 2014; NSB 2020; NSF n.d.).

Traditional Ecological Knowledge and Ways of Knowing

Traditional Ecological Knowledge (TEK) from Native American/Alaska Native (NA/AN) communities is typically disregarded by academia, and is erroneously perceived as merely qualitative. Careful consideration of what TEK is, what it embodies, and how it is informed, leads to the recognition that TEK is qualitative, quantitative, and spiritual knowledge that has been documented across significant expanses of time and is regionally specific. The resistance of mainstream society, specifically academia, to recognize the depth of knowledge within TEK and its refusal to acknowledge the rigor applied to its development as the same that is applied to Western science is a reflection of the ingrained ideologies of the superiority of Western knowledge systems to any other. TEK provides historical knowledge about place, and in-depth knowledge about the intricate relationships established between plants, animals, landscapes, watersheds, and other natural phenomena, this knowledge system encompasses a worldview that through its holistic nature considers multiple disciplines such as ecology, social science, human health, spirituality, and the relationship of people with their environment (Smythe et al. 2020).

TEK is dynamic varying between Native communities, as there are 574 federally recognized and 66 state-recognized tribes in the United States, of which each possess regionally specific and distinct knowledges, protocols, histories, cultural practices, and languages (NCSL 2020). The practice of combining the identities and experiences of individuals from distinct tribal communities into a single monolithic group and understanding of TEK is not only neglectful and harmful, but is in itself ill informed, falling away from everything Western science claims to be built upon. A simple definition of

Fig. 1. Alaska Native youth learn about forest and river ecology along a culturally important river in Southeast Alaska, discussing the scientific, cultural, and historical importance of place from an early age. Photo credit: W. Smythe.

science states that "it is both a body of knowledge of things already known and the process of acquiring new knowledge" (AAS 2020); how do we acquire new knowledge by dismissing knowledge systems that are tens of thousands of years old without regard of how they were developed and by whom? It is more reasonable to assume a TEK system will be comprised from a spectrum of beliefs, values, and perceptions, that refer to local and/or regional knowledge embedded in cultural traditions in one or more forms of collective abstracts, of diverse understandings, that include but are not limited to, language, art, dance, music, names, medicines, and remedies (Berkes et al. 2000, Downes 2000, Hoagland 2017, Smythe et al. 2020). Coupling of these two knowledge systems, TEK and Western science, provides great potential to create a new means for ecological research and education with an increase in ways of knowing and teaching, diversity, and innovation and can provide historical insight and sense of place (Durie 2004, Smythe et al. 2020).

Traditional ways of knowing is different from TEK in that Traditional ways of knowing referrers to an understanding of knowing how ecosystems function through both lived experiences or through oral traditions and is highly defined by one's view of the world.

Undiscovering Ecology

As previously stated, ecology and ecological understanding are an ingrained part of Indigenous culture taught throughout life within cultural and traditional use communities. It is upon entry into academia and thus ecological sciences that students are forced to undiscover, or disregard, what they have been taught and have known throughout their life, ways of knowing and understanding that have sustained not only their family and community but the existence of their communities since time immemorial. Here is where understanding of tens of thousands of years of ecological knowledge and phenomena are dismissed and invalidated in favor of a much younger, hundreds of years old, ecological discipline. Students are chastised and shamed for the perceived offense of inquiring about the place of long-standing TEK in ecological sciences. This stripping away of and dismissal of knowledge and shaming of students' identity result in the withdrawal of students from not only ecological sciences but all STEM disciplines and is a form of violence against racially diverse students that adds to an extensive list of historical traumas enacted upon students of color. The lack of value academia places on the lens Native American/Alaskan Native students bring to the classroom is often a deterrent and a constant obstacle that puts students at an unfair disadvantage.

Globally, Native peoples comprise roughly 5% of the population, however, these same people manage around 11% of forests, and utilize one-quarter of terrestrial ecosystems from tundra to plains and deserts in which they maintain approximately 80% of biodiversity on the planet. Despite their deep holistic knowledge and understanding of these ecosystems, ecological interactions, and outcomes, TEK systems are viewed as irrelevant, out of touch, uninformed, or outdated (Robbins 2018). TEK is only accepted as relevant when it is being discussed or presented by a non-Native "expert" who has gleaned some knowledge from TEK, where it is then interpreted through one's own worldview and repackaged as a new discovery. This is where Native people lose their voice, sovereign nations lose their agency to share their own intellectual property, and where TEK risks losing its intended purpose through misinterpretations.

Mainstream Ecological History

Ecology is a relatively new science, crediting Aristotle or his student Theophrastus as the first ecologists in the fourth century (McIntosh 1985). Examination of the history of ecology shows us an extensive list of men of European descent that begins with Aristotle's study of life, Antoine van Leeuwenhoek's discovery and description of microbial ecology in the 17th century, to Robert MacArthur's study of community and population ecology in the 20th century (Ramalay 1940, MacArthur 1967, Brown 1999). This short period of time spans approximately 2,402 yr and is revered and taught as the only valid knowledge system. Nowhere in the timeline of ecology can one find reference to Indigenous knowledge systems that span the many thousands of years over which they were developed. Due to a of lack of understanding of Indigenous people's methods of documenting and exchanging knowledge, these ancient and robust knowledge systems are typically disregarded (Nicholas 2019).

If ecology strives to gain in-depth knowledge and historical insight about place why does it continue to overlook the use of knowledge that has been developed and proven over thousands of years in favor of more current knowledge? Why then does it continue to overlook knowledge from Indigenous peoples from around the globe? Consider this: In 1854 Chief Si'ahl (referred to as Seattle) a Suquamish and Duwamish chief gave a speech arguing in favor of ecological responsibility and respect for Native American land rights. He discussed the connectedness of all living things and how environmental health impacts human health. This understanding of ecology reflects the subdiscipline of community and population ecology "discovered" by MacArthur in the 1960's, however, there is no mention of the ecological understanding of Indigenous peoples in ecology courses, it is taught as if such concepts did not exist until discussed by and from a Western perspective (Smith 1887; Duwamish Tribe 2009).

This purposeful erasure of not only TEK but all knowledge systems not rooted in Western society from all STEM fields is a deeply ingrained ideology embedded in systemic silent norms of Western society such that people of color are somehow lacking when it comes to intelligence leading to the undervaluing of knowledge systems. For example, there are a myriad of Native and Indigenous Ecology books and publications, however, few of these materials are authored or coauthored by Native and/or Indigenous scholars or cultural practitioners. Such norms must be examined, acknowledged, and brought to an end in order to usher in a new norm of diversity, equity, inclusion, and dignity for people of color. This idea presents a frightening reality to those who have enjoyed the privilege of being the unique Native ecology expert or TEK scholar as it requires acknowledging the intellectual labor of others, the reality and applicability of the existence of ancient knowledge systems, and that the discovery was in finding a preexisting knowledge, and finally in power sharing. Here power sharing is when one allows oneself to acknowledge what has already been known and practiced for generations, providing an opportunity for Native scholars and cultural practitioners to share their own knowledge as it was intended to be, without interpretation through a Western lens, and the dissemination of knowledge by those who discovered it. It is unheard of for a researcher to allow someone else to take credit for their discovery, why then is it acceptable for researchers to share TEK as their own discovery?

> The Earth does not belong to us. We belong to the Earth
> This we know: All things are connected, whatever befalls the Earth befalls sons of the Earth
> ~Chief Si'ahl, 1854

> Áajii Wáadluu wáan uu gúu daahl Kíiwaagan (All things are connected, and we need each other to survive)
> ~Haida saying

Factors Influencing Diversity

In field-based disciplines, students are presented with a unique opportunity to engage in a variety of field experiences broadening their exposure to place- and inquiry-based authentic research shaping their science identity and defining their research specialty. Even so, social factors, such as sense of belonging, science identity, exposure to implicit biases and stereotypes, environment (welcoming vs. unwelcoming), lack of role models/mentors or peers have all been explored and are known to influence the participation of diverse students in science disciplines (Freeman et al. 2007, Walton and Cohen 2007, Gullory and Wolverton 2016, Carpi et al. 2017, Smythe et al. 2020). These factors coupled with the potential isolation and lack of security encountered in field experiences can result in the withdrawal of students from field based disciplines.

Careful consideration, planning, and implementation of interventions to ensure students feel secure and included can have a notable impact on science learning gains (Fig. 2). Activities can be as simple as acknowledging the historical significance of a research site and will result in retention of students of color (Walton and Cohen 2007, Walton and Cohen 2011). For example, asking questions such as, "Who occupied the lands prior to colonization? What was the relationship to the space, seasonal hunting and gathering or shelter? Is it a

Fig. 2. Alaska Native undergraduate environmental science students conducting field research on their tribal lands in Southeast Alaska along a culturally significant river. Photo credit: C. Fetes.

spiritual or sacred site?" acknowledging who established the site (e.g., Indigenous, slaves, etc.). All too often these are aspects scholars want to overlook; however, this is an important piece of history and body of knowledge and can no longer be ignored because it brings discomfort. Additional interventions to consider are (1) team-building activities to build confidence and a sense of belonging, (2) use of materials of ecologists of color, (3) development of critical thinking by presenting multiple ways of knowing and thinking, (4) continued learning by faculty of issues around diversity in science disciplines as academia should be prepared to accommodate all students, and (5) assessment of student opinions as to the inclusivity of ecology courses and experiences to better inform best practices each of which will work together to provide a secure equitable and inclusive space for all students and faculty (Cid and Bowser 2015; Fig. 3).

Future of Ecology

Only recently have ecologists started the journey of asking, listening, and applying TEK in order to have a deeper understanding of the natural world (Robbins 2018). Applying this holistic view of ecology allows researchers to not only gain an understanding of short-term (immediate) ecological knowledge but provides access to long-term (generations) ecological interactions and phenomena. This new practice has far-reaching applications not only for ecology but for all science disciplines. For instance, applied ecology always takes place on Native land meaning that there will always be a story and history of place, a spiritual connection that the United States has tried to erase and that academia chooses to overlook. Ecological research and education would be more impactful and more meaningful if it looked at these historical connections to land, examined what made a place sacred and what caused the formation of spiritual connections. These in-depth examinations is where knowledge is gained, innovation happens, and critical thinking occurs.

An example of this is illustrated by reclamation efforts in northern Minnesota along the Iron Belt where restoration efforts by mining companies to return the environment to usable habitat and to reestablish Native cultural sites. This is being done by rebuilding hills and mounds from expended iron tailings, establishing plants on these mounds and monitoring the ecological succession of plants and animals. However, what is not understood is that there is no reestablishing of sacred cultural sites; the land, through the process of removing entire landforms for the purpose of iron extraction, is made different and thus the connection to the land is forever gone, removed in one massive scoop of Earth laden with iron ore. Restoration efforts that claim to reestablish cultural sites would benefit from consultation with Native communities in order to make meaningful efforts at habitat restoration and to gain an understanding that, once removed, the land is forever changed, the spiritual connection lost, otherwise claims of cultural restoration are merely superficial.

Fig. 3. Faculty attending the FIELD Institute at Colorado State Universities Mountain Campus. FIELD provided professional development training for faculty and field researchers around issues of diversity, equity, and inclusion in order to create safe spaces for students and faculty of color in field sciences. Photo credit: Lisa White.

As we move into the next decade, there is hope that science disciplines will do a thorough examination of common practices and consider if they are truly inclusive, in an effort to not only move forward to ensure students feel secure and welcome, but also to increase our innovation and productivity as scientists and stewards of the Earth.

> The trees of the forest is our grandmother. Her deep roots hold knowledge and her rings the history of this place, she tells us the climate of forest that drives ecology.
>
> ~Haida elder

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Literature Cited

Australian Academy of Science. 2020. What Is science? Reviewed by P. Ladiges, P and O. Mayo. https://www.science.org.au/curious/people-medicine/what-science

Beck, C. K., C. S. Boersma, C. S. Tysor, and G. Middendorf. 2014. Diversity at 100: women and underrepresented minorities in the ESA. Frontiers in Ecology and the Environment 12:434–436.

Berkes, F., J. Colding, and C. Folke. 2000. Rediscovery of traditional ecological knowledge as adaptive management. Ecological Applications 10:1251–1262.

Bowser, G., and C. R. Cid. 2021. Developing the ecological scientist mindset among underrepresented students in ecology fields. Ecological Applications: e02348. https://doi.org/10.1002/eap.2348

Brown, J. H. 1999. The legacy of Robert MacArther: from geographical ecology to macroecology. Journal of Mammalogy 80:333–344.

Carpi, A. L., D. M. Ronan, H. M. Falconer, and N. H. Lents. 2017. Cultivating minority scientists: undergraduate research increases self-efficacy and career ambitions for underrepresented students in STEM. Journal of Research and Science Teaching 54:169–194.

Chief Si'ahl and His Family. 2009. Culture and History. Archived from the original on 2009-02-13. Duwamish Tribe, Seattle, Washington, USA.

Cid, C., and G. Bowser. 2015. Breaking down barriers to diversity in ecology. Frontiers in Ecology and the Environment 13:179.

Downes, D. 2000. How intellectual property could be a tool to protect traditional knowledge. Columbia Journal of Environmental Law 25:254–257.

Durie, M. 2004. Understanding health and illness: research at the interface between science and indigenous knowledge. International Journal of Epidemiology 33:1138–1143. https://doi.org/10.1093/ije/dyh250

Freeman, T. M., L. H. Anderman, and J. M. Jensen. 2007. Sense of belonging in college freshmen at the classroom and campus levels. Journal of Experimental Education 75:203–220.

Guillory, R. M., and M. Wolverton. 2016. It's about family: Native American student persistence in higher education. Journal of Higher Education 79:58–87.

Hoagland, S. J. 2017. Integrating traditional ecological knowledge with western science for optimal resource management. IK: Other Ways of Knowing 3:1–15. https://doi.org/10.18113/P8ik359744

Lawrence, D. M., M. M. Holland, and D. J. Morrin. 1993. Profiles of ecologists: results of a survey of the membership of the Ecological Society of America. Part I. A snapshot of survey respondents. Bulletin of the Ecological Society of America 74:21–35.

MacArthur, R., and E. O. Wilson. 1967. The theory of island biogeography. Princeton University Press, Princeton, New Jersey, USA.

McIntosh, R. P. 1985. A background of ecology: concept and theory. Cambridge University Press, New York, New York, USA.

National Conference of State Legislatures. 2020. Federal and State Recognized Tribes. NCSL, Denver, Colorado, USA.

National Science Board. 2020. The state of U.S. science and engineering 2020 report. https://ncses.nsf.gov/pubs/nsb20201

Nicholas, G. 2019. An uneasy alliance: Indigenous Traditional Knowledge enriches science. The Conversation. https://theconversation.com/an-uneasy-alliance-indigenous-traditional-knowledge-enriches-science-109212

NSF n.d. National Science Foundation Broader Impacts criterion. https://www.nsf.gov/pubs/2002/nsf022/bicexamples.pdf

Ramalay, F. 1940. The growth of a science. University of Colorado Studies 26:3–24.

Robbins, J. 2018. Native knowledge: What ecologists are learning from indigenous people. Yale Environment 360. Yale School of the Environment, Yale University, New Haven, Connecticut, USA.

Smith, H. A. 1887. CHIEF SEATTLE'S 1854 ORATION - ver. 1. http://www.halcyon.com/arborhts/chiefsea.html

Smythe, W. F., J. Brown Clarke, R. Hammack, and C. Potra. 2020. Native perspectives about coupling indigenous traditional knowledge with western science in geoscience education from a focus group study. Global Research in Higher Education 3:10.

Walton, G. M., and G. L. Cohen. 2007. A question of belonging: Race, social fit, and achievement. Journal of Personality and Social Psychology 92:82–96.

Walton, G. M., and G. L. Cohen. 2011. A brief social-belonging intervention improves academic and health outcomes of minority students. Science 331:1447–1451.