esa ECOSPHERE

INNOVATIVE VIEWPOINT

How do we ensure the future of our discipline is vibrant? Student reflections on careers and culture of ecology

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Abstract. Ecology must attract and retain diverse talented people to produce innovative research and relevant solutions to 21st-century environmental problems. Careers and culture form the foundation of scientific advancement, and substantial progress has been made over recent decades in both realms. Yet, important challenges persist in expanding career paths, inclusion of underrepresented groups, and communication with the public. The ESA Student Section organized a horizon scanning exercise to address the following goals: (1) to identify challenges that 21st-century ecologists contend with or expect to contend with in careers and outreach to society, (2) to anticipate opportunities to help ecologists meet challenges, and (3) to identify concrete steps that could be taken by individual laboratories, institutions, and the ESA to foster progress. In spring 2016, the ESA Student Section solicited input from student members and organized a working group to assess the state of the discipline and to envision how we might cultivate a more inclusive and effective community. We identified three major challenges. First, PhDs are produced faster than academic positions become available and disconnects between academia and other sectors may keep early-career ecologists from realizing the breadth of available positions. We propose an online jobs hub to make non-academic sectors more accessible to ecologists. We also suggest students develop skills portfolios to prepare for non-academic positions. Second, the composition of people who are ecologists differs from broader society, partially due to implicit biases and institutional barriers. We propose steps to reduce attrition of diversity in ecology that include countering implicit biases and creating mentorship networks. We offer steps to improve recruitment by increasing awareness of ecology among high school students and undergraduates and providing opportunities to engage in ecological research. Finally, ecology is only relevant if the public perceives it to be. We must improve science communication and begin cultivating trust. We propose that ad hoc communication by all ecologists is insufficient;

translational ecologists should be hired in every department and formal training in translational ecology is necessary. We hope this paper catalyzes critical thinking and partnerships among students, professional ecologists, and the ESA to ensure the future of ecology is vibrant.

Key words: careers; Ecological Society of America; inclusion; science communication; students.

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Introduction

Ecology thrived during Ecological Society of America's (ESA) first 100 yr; ecologists made profound advancements in our understanding of nature and directly informed several landmark environmental policies (Inouye 2015). The need for ecology will only grow in the 21st century as novel environmental challenges emerge. Solutions will require ecological expertise sustained by innovative research (Turner 2015). To ensure ecology flourishes and continues to support responsible environmental decision-making, the field must attract and retain talented and curious people, develop new career paths, cultivate an inclusive community, improve communication with the public, and continue producing cutting-edge science.

Careers and culture in ecology form the foundation of scientific advancement (Fig. 1). The ways students are trained, the laboratory environments they encounter, and the career paths available to them will determine who chooses to become a 21st-century ecologist and the sectors in which ecologists are embedded (Armstrong et al. 2007, Pouyat et al. 2010, Fuhrmann et al. 2011, Haynes and Jacobson 2015). In turn, the diversity of voices in ecology will shape which scientific questions are asked. Effective communication of that science with the public will determine the relevance of ecology in society (Pace et al. 2010, Simis et al. 2016). We must holistically consider ecology's future: the science, the scientists, and the culture in which scientists work (Fig. 1). Ecology as a discipline has made great strides over recent decades, and yet, challenges regarding career paths, inclusion, and communication with the public persist (Campbell et al. 2005, Beck et al. 2014, McGlynn 2017).

In this paper, we evaluate where careers and culture of ecology stand and envision how we might cultivate a more inclusive and effective scientific community that is highly regarded by the public. The ESA Student Section organized a horizon scanning exercise with student members. The objectives were (1) to identify a set of pressing challenges that 21st-century ecologists currently contend with or expect to contend with in their careers and outreach to society, (2) to anticipate emerging opportunities to help ecologists meet these challenges, and (3) to identify concrete steps that could be taken by individual laboratories, institutions, and the ESA to address these challenges. We propose some directions for progress in expanding career paths, making ecology more inclusive, and improving science communication. We think all three areas are important to emphasize because of their interlinked nature and the role that each plays in the vibrancy of our discipline, but we recognize they are a subset of the challenges ecology faces. Our proposed solutions are not panaceas. However, our goal is to catalyze reflection among ecologists and spur innovation. We hope this paper serves as a foundation for vigorous action.

Horizon Scanning Exercise

In spring 2016, the ESA Student Section asked their members to reflect on the following prompt: "What are the most important challenges you expect to face and new opportunities you hope to capitalize on in your ecology career and outreach to society?" Students were asked to submit up to five challenges and five opportunities as short responses (~140 characters) through our online portal. Forty-eight students participated and

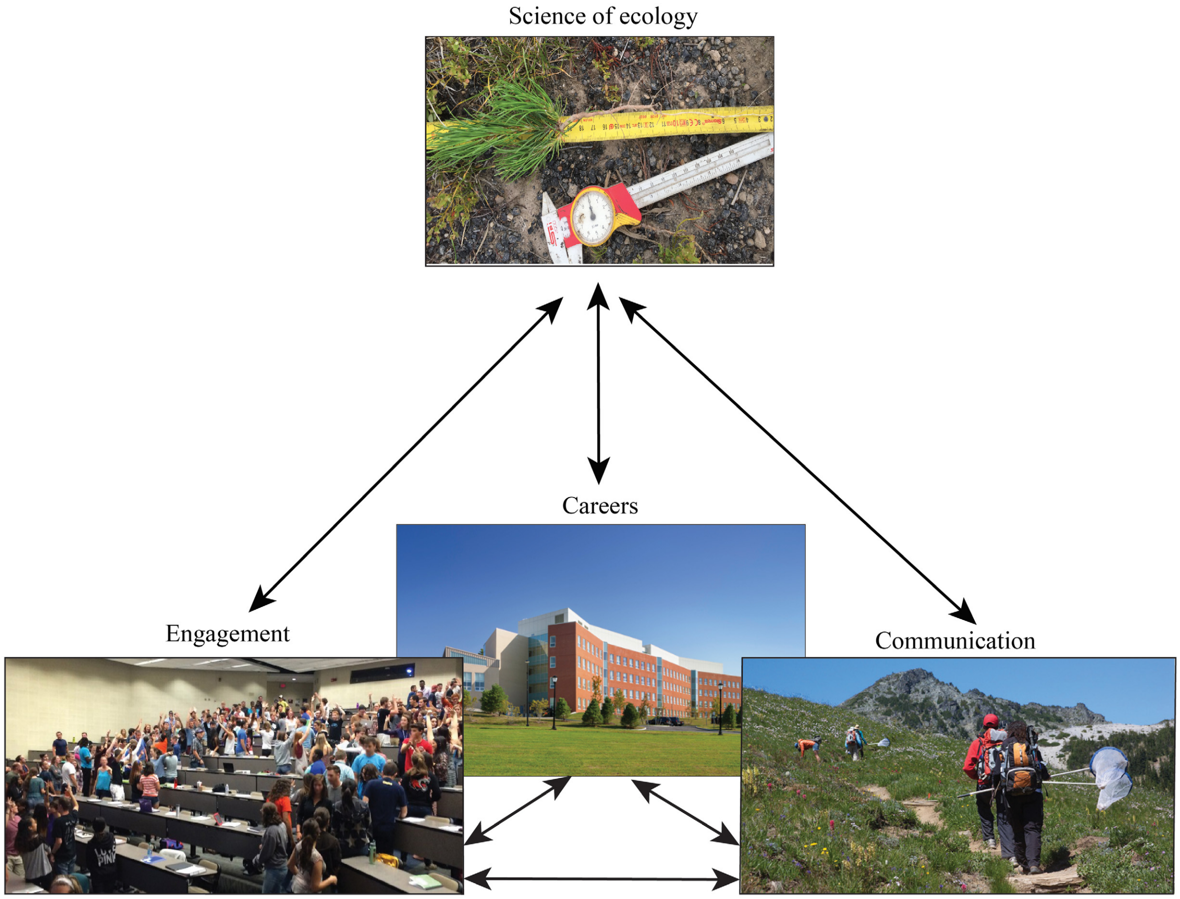

Fig. 1. Careers in ecology, engagement in ecology, and communication of ecology form the foundation of the science of ecology. This means the future of the field should be considered holistically.

submitted 171 challenges and 157 opportunities. Challenges covered diverse topics, including best practices in the big data era, wildlife conservation, climate change, work–life balance, employment opportunities, political reticence to science, and funding opportunities (Box 1).

Box 1.

Examples of challenges submitted by student ecologists as part of the EcoFutures horizon scanning exercise

"Instead of 'publish or perish' it's now 'fund or get fired.' Funding to advance science will be one of the greatest issues for next-gen scientists."

"Successful communication to the public regarding specific findings, the scientific process, and evolution of progress in the natural sciences."

"Institutional barriers to inclusion of underrepresented groups (in the career track as well as in broader society)."

"Changing the graduate school system to facilitate better training and preparation of future ecology students for diverse career paths (e.g., 'alt ac' careers)."

"As society becomes further removed from the environment they are less likely to see the importance of protecting and caring for natural resources."

The Student Section also organized a working group to prioritize and synthesize submitted challenges and opportunities. Students interested in participating in the working group were asked to submit a short application. Sixteen people were chosen (all that applied), including the authors of this paper. Members of the working group were from universities around the country and included undergraduate and graduate students, women and men, and reflected a diversity of cultural and racial identities. The working group met in a series of online plenary meetings and breakout groups. The working group first decided on topics used to categorize submissions. Topics were ranked in order of importance based on the number of student submissions and a poll of the working group (Fig. 2). Topics were then grouped into three overarching themes, including expanding ecology-career opportunities, dissolving barriers to engagement in ecology, and improving communication of ecology (Table 1). Subgroups were organized around each theme. An in-person working group meeting was held at the ESA 2016 annual meeting in Fort Lauderdale, Florida, USA, to assess and finalize results.

Expanding Ecology-Career Opportunities

Barriers

Science PhDs are produced faster than academic positions become available (Cyranoski et al. 2011). In the last two decades, twice as many life-science PhDs were awarded as the number of available academic jobs (NSF 2015; Fig. 3). Non-academic positions exist; however, graduate training in ecology often equips students with skills important for success in academia, sometimes at the expense of developing transferable skills that are important for success outside of academia (Campbell et al. 2005, Fuhrmann et al. 2011). For example, 88% of ecology students surveyed in the National Doctoral Program Survey (NAGPS 2001) reported receiving adequate research training, but 57% reported insufficient training in teaching and mentoring and 27% in public speaking (Campbell et al. 2005). Academics often have limited experience with non-academic careers or the skills required for success outside universities, and there remains a lack of incentives for professors to train non-academics (Nerad 2004, Schillebeeckx et al. 2013). Aspiring ecologists are concerned about their job prospects, something that discourages people from pursuing graduate degrees.

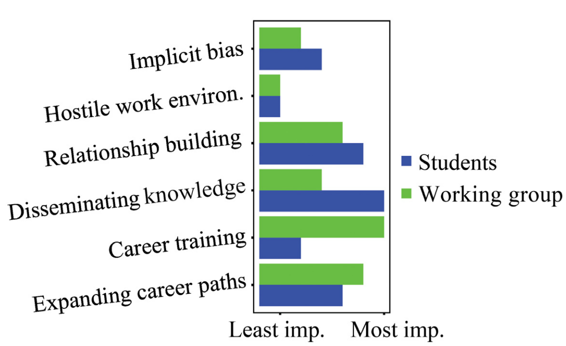

Fig. 2. Challenges in careers and culture of ecology prioritized by students who submitted challenges (based on number of submissions in each category) and by working group members (based on poll).

Solutions

Unemployment data suggest non-academic ecology jobs exist and resources to help students prepare for and locate these positions are increasing. Perceived scarcity of ecology jobs may be a consequence of disconnects between academia and other sectors employing ecologists. Unemployment rates for doctorate holders tend to be very low (~2%), and most employed doctorate holders (~93%) work in a field related to their degree (Auriol et al. 2013). Many universities and professional societies, including the ESA, have programs to provide students with resources and training for non-academic job markets (Campbell et al. 2005, Whitmer et al. 2010, AAAS 2017). Graduate students also develop many transferable skills, such as managing teams, fundraising, and budgeting, but may not know how to market them in non-academic job applications and interviews.

We can close gaps between academic and non-academic sectors by leveraging existing efforts of professional societies and universities to connect students to the broader ecology-job market. We envision the creation of a centralized digital ecology jobs hub led by the ESA and supported by federal and private agencies and universities where students can locate a diverse range of available ecology jobs in a single Web interface.

Table 1. Challenges, solutions, and metrics of success in careers and culture of 21st-century ecology.

Challenge	Solution	Implementer	Timescale	Metrics of success
Ecology careers	Online careers hub	ESA	Five years	Increased recognition of non-academic careers and emphasis on transferrable skills within five years
	Transferrable skills portfolio	Ecology departments	Immediately	
Engagement	Counter individual bias	Scientists	Immediately	Reduced attrition of scientists and broader recruitment from underrepresented groups within five years
	Mentor networks	Universities	Five years	
	Best hiring practices	Ecology departments	Immediately	Strong connections between academic and non-academic sectors by 2030
	Actively recruit students	PIs	Immediately	
	Increase exposure of children to ecology/ecologists	ESA	Five years	
Communication	Translational ecology workshops	ESA	2018 conference, annually thereafter	Increased recognition of translational ecology as a sub-discipline within five years
	Frontiers in Ecology and Evolution Translational ecology special issue	ESA	2018, bi-annually thereafter	Majority of departments hire a translational ecologist and offer courses by 2030
	Hire translational ecologists	Ecology departments	15 yr	Ecology graduate students are exposed to best practices in science communication
	Science-communication curricula in graduate training	Ecology departments	15 yr	

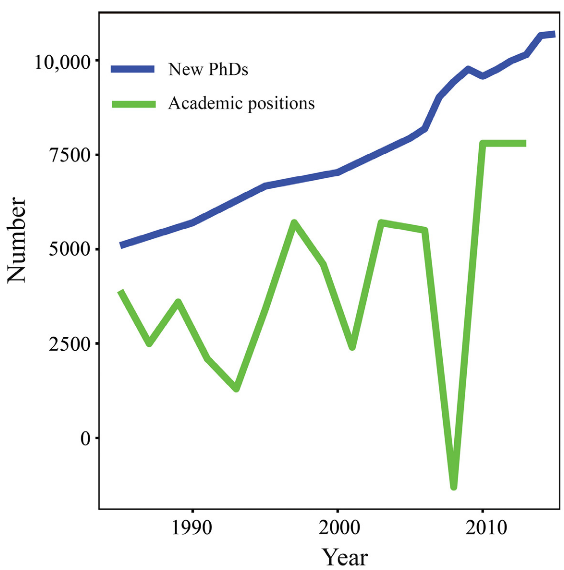

Fig. 3. The number of life-science PhDs awarded annually in the United States from 1985 to 2015 and the number of new academic positions (tenure-track faculty, adjunct faculty, postdoctoral associates, lecturers) that became available each year from 1985 to 2013. The data stem from the NSF Survey of Doctorate Recipients (NSF 2016*a*) and the National Science Board Science and Engineering Indicators (NSF 2014*b*, 2016*b*), respectively. For all data in this figure, health-care-related fields were removed.

The hub could be modeled after sites such as the AAAS science careers hub (AAAS 2017) and would likely be self-sustaining and profitable for the ESA after an initial investment, which could be funded by federal agencies already eager to invest in training for diverse careers (Nerad 2004). The site would differ from AAAS in being specific to ecology and more customizable for the user. For example, by creating a short but detailed profile, users would be able to take advantage of job-matching algorithms (e.g., Roth 2015). Ultimately, we envision this hub to provide more interactive content and advanced search features (e.g., by salary, geographic location) and facilitate more direct interactions between employers and employees than other job sites. For employers and students, the site could offer free basic functionality with options to upgrade for enhanced features. We expect the centralized nature of the jobs hub would also be an appealing selling point to employers who are looking for a new well-trained pool of potential employees.

A jobs hub would accomplish three goals and seems feasible given the ESA's resources and existing efforts. First, it would provide a valuable ESA-member service to students and recruiters within and outside academia, helping grow membership (Lymn et al. 2014). Second, it would provide revenue for the ESA through advertising, user fees, and increased membership. Third, by encouraging students and recruiters to create accounts, the ESA could collect data (e.g., demographics, desired membership services) that provide insights into membership needs/program success (e.g., Lockwood et al. 2013). The ESA maintains a job board, is invested in exploring non-academic careers (e.g., ESA 2016), and commands a large membership (Lockwood et al. 2013). This entrepreneurial endeavor is an important extension of existing efforts and would help the ESA adapt to shifting economic trends (Etzkowitz et al. 2000).

As the number of career tracks expands, students need to be prepared. We feel a bottom-up and top-down approach initiated by students and university administrators to sharpen transferable skills and articulation of those skills is needed (Schillebeeckx et al. 2013). We propose the portfolio approach, not unlike portfolios used by professionals in architecture and business, but tailored for a career in science (Manathunga and Lant 2006). The student, with advice from their graduate committee, would complete an action plan, honing skills (e.g., oral and written communication, data analysis, budgeting, and business management), while amassing a portfolio highlighting transferrable skills (e.g., GIS projects, statistical analyses, public talks, multimedia products), which later serves as a resource to articulate and demonstrate skills during job applications. The ESA Student Section, Education Section, and Education Office could promote this initiative and provide resources on how to implement a portfolio approach.

Although the portfolio approach is intended to complement, not impede, research, some advisors may view it as counterproductive. People may feel that time spent preparing for a non-academic career will take away from time spent on research and publications. However, studies show that transferable-skill development increases research productivity (Davis 2009). Additionally, it is possible to alleviate conflict of interest by assigning career-development responsibilities to a student's committee because they may offer a broader perspective on career training unbiased by laboratory-specific research deadlines (Fuhrmann et al. 2011). Students can also seek out faculty members for committees with experience in non-academic sectors.

Ensuring ecology students find careers and are well-trained is crucial for advancing 21st-century ecological science. Drastic reforms to graduate education have been proposed to meet this goal (Campbell et al. 2005). Although inspiring and necessary, these are long-term and require profound changes (i.e., shifting from the publications/citation currency). However, leveraging existing opportunities and partnerships between ecologists and the ESA could collectively address pressing ecology-career challenges with minimal reform to existing academic culture (Table 1). In the short term, we expect our recommendations to bolster awareness of non-academic careers and encourage emphasis on transferable skills. In the long term, our recommendations could lead to strong connections between academia and non-academic sectors providing smooth transitions to the workforce for students. We envision ecologists becoming embedded in increasingly diverse sectors, contributing to a more informed and sustainable society.

Dissolving Barriers to Engagement in Ecology

The composition of people who are ecologists continues to differ from broader society (Cid and Bowser 2015). We have made progress in recent decades, despite structural barriers (O'Brien et al. 2015). For example, the proportion of biological and biomedical science PhDs in the United States (which includes ecology) received by women has risen from 48% in 2005 to 53.2% in 2015 (NSF 2017), and for the limited national data available specific to ecology (2015 is the only year), women received 51% of PhDs. However, women and minorities remain vastly underrepresented at multiple career stages in ecology. Of the people who received ecology PhDs in 2015, 85% were white, 1% were black or African American, 2.6% were Asian, 6.4% were Hispanic or Latino, and 0.5% were American Indian or Alaska Native. This underrepresentation is also reflected in academic employment of PhDs. Approximately 40% of biology/agricultural/environmental life-science PhDs employed at four-year colleges and institutions were women in 2013, 0.2% were American Indian or Alaska Native, 2.2% were black or African American, 4.6% were Hispanic or Latino, and 18% were Asian (NSF 2014*a*). In ecology, women represented 37% of ESA membership in 2010, and the proportion of minorities in the ESA was threefold smaller than in the U.S. population (Beck et al. 2014). Lockwood et al. (2013) reflected that "Today's model ecologist is a 55-yr-old male professor. . . ." Although not evaluated, we could safely add white to this description.

Excluding people from ecology has profound and systemic consequences. It is unethical and constrains scientific progress. Diverse teams develop more innovative science, publish in higher impact journals, and are cited more often (Nielsen et al. 2017). Exclusion also impacts how people perceive ecology and our ability to communicate its importance to the public (Snijders and Keren 2001, Archer et al. 2010). As the composition of society changes, increasing diversity in ecology could help us better understand social concerns and better engage in public discourse.

Barriers

Barriers persist at individual and institutional levels that hinder the retention and recruitment of people from underrepresented groups. Implicit bias is a persistent problem at individual levels in Science Technology Engineering and Math (Reuben et al. 2014). Implicit biases are attitudes or stereotypes that unconsciously affect actions and decisions, leading to both favorable and unfavorable evaluations of people (Blair 2002). As just two examples of many, gender bias has been documented in introductory ecology text books (Damschen et al. 2005), and in distinguished speakers at professional ecology conferences (Farr et al. 2017).

Implicit biases are a barrier to recruiting and retaining people of underrepresented groups at all career stages. For high school and undergraduate students, exposure to relatable role models and gaining research experience are key determinants of whether students choose to pursue ecology careers (Armstrong et al. 2007, Shin et al. 2016). The types of students who get these opportunities, thus, strongly determine who is recruited into graduate school in ecology. The most stressful and insecure portions of ecology careers (early career) also coincide with periods in which people often start families (Goulden et al. 2011, Adamo 2013). This can hinder the retention of women in STEM fields when departmental expectations and family leave policies are inflexible and biased toward success of male academics.

Institutional barriers that constrain retention and recruitment also remain in ecology. Senior ecologists generally remain in positions for many years. Thus, turnover is low and competition is high when positions become available, particularly in academia. Slow turnover keeps homogenous groups from diversifying (O'Brien et al. 2015), and thus, demographics of ecologists lag behind demographics of society. At the other end of the ecology-career timeline, entry-level jobs (field crews, laboratory technicians) are often low or non-paying and people from less privileged socio-economic backgrounds generally cannot forgo salary (Fournier and Bond 2015). This keeps people from gaining early experience, a prerequisite to a successful ecology career.

Solutions

Creating an inclusive field will require capitalizing on windows of opportunity during ecology-career pathways and improving the culture of ecology, so people from diverse backgrounds feel welcome and can see themselves as ecologists. We should consider both retention and recruitment. In the short term, we must better prioritize retaining people from underrepresented groups who have already chosen to become ecologists. In the longer term, systematic changes, such as increasing the accessibility and relevancy of ecology as a discipline, are needed to foster broader recruitment.

To better retain people, we first need to create a non-threatening environment where people feel valued (Eagan and Garvey 2016). An important step is for all ecologists to confront and counter their own implicit biases. Harvard's Project Implicit provides tests to evaluate individual implicit associations (Project Implicit 2016). Take the tests. See where you fall! The Kirwan Institute at Ohio State University releases an annual review of implicit-bias research with extensive information on techniques to counter bias (Staats et al. 2016). Consider applying these. Departments and institutions will all differ in the aspects of their environment they need to address. We must foster open constructive dialogue in our laboratories and departments about what needs to be done to rectify the attrition of women and minorities from STEM. Conversations are critical for initiating substantive change. At your next laboratory meeting discuss what steps you can take, evaluate how you recruit students, and critically reflect on departmental expectations and family leave policies.

Formal mechanisms that help people succeed in ecology careers are also necessary. People who are different from those around them often feel isolated (Dagsputa et al. 2015). Isolation is detrimental because networking is critical for advancement in ecology. One solution is to develop mentoring programs that pair senior scientists with junior scientists, based on similarities beyond research. For early-career scientists, having a trusted confidante to talk with about challenges of being from an underrepresented group may help reduce isolation, foster networking, and create important professional development opportunities. Many such networks exist, such as the Earth Science Women's Network (https://eswnonline.org/), and we urge expanded adoption of this approach. Mentorship would be particularly beneficial in rural regions, particularly if multiple universities coordinate to form networks. We expect widespread creation of mentorship programs could occur quickly, with relatively low cost.

The hiring process is also an opportunity to foster diversity, and many departments are making substantial changes in how faculty searches are conducted. The University of Michigan, for example, developed the Committee on Strategies and Tactics for Recruiting to Improve Diversity and Excellence (STRIDE) which ensures that resources about hiring best practices are available, that best practices are applied, and that they result in diverse applicant pools and hires. These include selecting a diverse hiring committee, using broad language in advertisements, seeking a diverse applicant pool through informal networks, only asking for reference letters from top candidates, including graduate students, and conducting blind reviews of applications. We urge all ecology departments to apply these practices if they are not already. Regardless of whether faculty searches are conducted progressively, relatively few positions become available in the first place. Reconceptualizing ecology careers and seeking out new sectors in which to employ ecologists will help us better retain early-career scientists, including underrepresented groups.

We must also develop and strengthen feedback loops to better recruit people. Let us all actively encourage promising undergraduates from underrepresented groups to apply to graduate school and mentor them through applications. Ecology is a small field and suffers from the invisibility problem. Few people know what an ecologist is, fewer have met one, and many students feel they are not smart enough to be scientists (Box 2; Fig. 4). We can combat this perception by promoting interactions between ecologists and students to increase the recognition of ecology as a rewarding career path and that ecology is important. We could set a simple but ambitious goal that every student in the United States meets an ecologist before finishing high school. After high school, the ESA could organize STEM-skills workshops for students at two-year colleges and historically black, Hispanic, and Indigenous institutions. The ESA would be an excellent organization to lead because of their national reach and pre-existing successful initiatives (e.g., SEEDS). Much of the organization and coordination could be conducted online, keeping program costs reasonable, though external funding would be necessary. The ESA could encourage ecologist participation by providing discounted memberships to volunteers and program participants.

Dissolving barriers to engagement in ecology is critical. We propose solutions at multiple scales and hope in the short term our suggestions will reduce attrition of those who are already ecologists (Table 1). Ultimately, we hope that demographics of ecologists at all career stages will reflect that of broader society.

Improving Communication: The Era of Translational Ecologists

Barriers

Effective communication of ecology to the public can facilitate scientific progress (increased funding, appreciation of science; Sturgis and Allum 2004). Beyond direct benefits, scientists often hope that the public uses science to guide decision-making (e.g., protecting wildlands, reducing carbon emissions). Traditionally, much of science-communication efforts have happened through a few select modes: professional science journalism, disseminating white papers, and mass-media endeavors by charismatic, well-known scientists (e.g., Carl Sagan, Bill Nye, Neil DeGrasse Tyson). However, we are at a turning point in the information-communication landscape. There is unlimited

Box 2.

Demystifying the ecologist: an online database of ecologist role models

One barrier to engagement in ecology is that some students (including those from underrepresented groups) can perceive career paths in science as either not attainable for people from their background (e.g., the misconception that science is only for white males) or that careers in science are repetitive, laborious, and unrewarding. A key to countering these perceptions is to expose students to the diverse career pathways of established ecologists. The only way students get insight into career pathways and trajectories is by directly asking questions to such professionals or if they are lucky enough to have a mentor that shares their wisdom and history; CVs and resumes flatten time and do not depict the historical development of the professionals for which we seek as models of our own career pathways. Therefore, we thought it was important to develop visualizations of career pathways to help others toward the realization of what it really means to be an ecologist, both personally and professionally. What do ecologists actually do day-to-day? What are the rewards of being an ecologist? What are the diversity of pathways that lead different types of people, with different strengths and weaknesses, to become ecologists?

We propose an online resource to visually demonstrate the diversity of pathways that have led ecologists to this discipline. The objective would be to help demonstrate the personal side of becoming an ecologist, to identify where today's ecologists came from, and to show the weaknesses and dead ends they overcame along the way. Ultimately, we envision a database of profiles that students can explore to find ecologist role models they can relate to personally, because of similar pathways, for example. These profiles would include a narrative description and a network diagram that visually represents their path (Fig. 4).

To create the network diagrams, we developed an approach where career histories could be mapped in a manner that allowed consistent comparison between different people. A person's career is first depicted as a set of nodes for each job they held in the past. Each node (job) is associated with a set of smaller nodes, defined by knowledge or skills that were acquired during the job. We categorized knowledge gained or applied (learned objects) into a set of overarching categories (technical skills, leadership/management skills, general science skills, and discipline/topic of study). The transfer of learned objects between jobs was depicted as connecting arrows. To create a common set of learned objects that would facilitate comparison between people, we extracted keyword descriptions of professional and technical skills from our personal social network of ecologists in LinkedIn and ResearchGate. We supplemented the list with a set of keywords for general life events. The visual comparison between each person's career pathways might help to reveal patterns and nuances that are not readily apparent in text descriptions of career histories.

capacity to produce and access information and influence its dissemination. The risks of digital misinformation are pervasive (Howell 2013). The traditional modes of science communication are not effective in this evolving environment and simply increasing information dissemination will not suffice if we wish to gain public trust and influence policy (Groffman et al. 2010).

Scientists are increasingly asked to do the bulk of science communication, as traditional science journalism positions are lost but outreach expectations grow (Pearson 2001). However, science is nested in a social system (Simis et al. 2016) and most ecologists do not have formal training in social-science theory to help navigate complexities of science communication. Thus, an underappreciation for social-science theory can make communication ineffective and potentially initiate long-term barriers between scientists and the public. Scientists often assume the public receives and processes information rationally (Simis et al. 2016). However, people often reject science that goes against their values (Lewandowsky and Oberauer 2016), as public perceptions of science are shaped by ideology (Baldwin and Lammers 2016), prior experiences (Leiserowitz et al. 2006), and the nature of their relationship with the scientist who is communicating (Shapin and Schaffer 1985). Many topics that ecologists study (e.g., climate change and evolution) are politically and socially charged. The public may respond to ecological findings through the lens of solution aversion, or motivated disbelief because findings conflict with individual identities (Campbell and

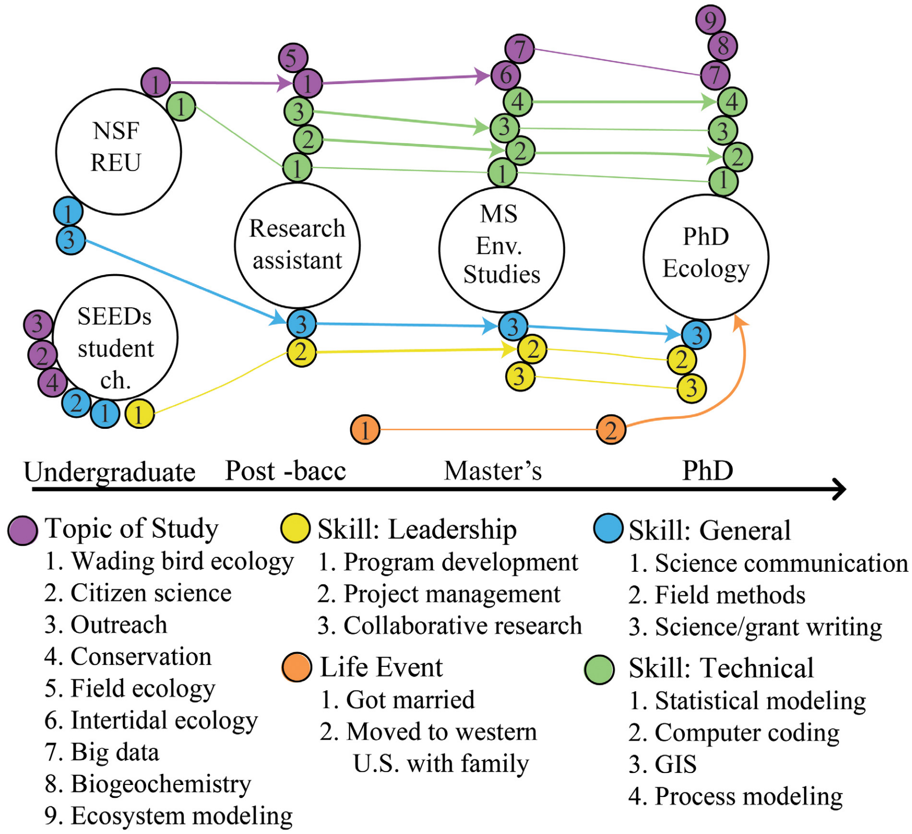

Fig. 4. Career-pathways network diagram for Leonardo Calle. Thick arrows represent accumulated skills that were particularly important for securing the next position. Thinner lines represent skills that were directly used in the subsequent position. LC's pathway was simplified for publication. A full version could include failures and dead ends as well as information on funding and grants.

Kay 2014). Thus, communicators must understand and address the lens through which their audience views science.

The public is also generally not equipped to deal with inherent properties of the scientific process, such as uncertainty, long timescales, and abstract concepts. Unfamiliarity with the scientific process can make it difficult for people to recognize how findings relate to and impact their lives. The public often expects concrete solutions, but when there is incomplete information or scientific understanding evolves, authority of science is undermined (Makri 2017). Unfamiliarity with the scientific process may stem from science education where inquiry-based learning is often not prioritized (Crawford 2007) and memorization for high-stakes testing is status quo (Preus 2012). Without having learned how to evaluate and put in perspective scientific evidence and uncertainty, the public lack the capacity to make judgments about science and instead rely on emotions and personal values in decision-making (Makri 2017). Social complexities and nuance embedded within effective science communication need to be accounted for in future communication endeavors. Current STEM training does not prepare students to understand or embrace this complexity (Smith and Gunstone 2009).

Solutions

If we are to effectively communicate ecology, we should move beyond emulating others who we think are good communicators without understanding why or how communication is effective. We need to implement an intentional communication strategy that includes (1) widely accessible training in communication best practices and (2) engaging with research on science communication in a rigorous framework informed by theory. Such an approach would start to address the mechanisms that underpin effective science communication. We do not expect all ecologists to conduct science-communication research, but if ecologists are going to engage in science communication, they ought to be formally trained and understand and appreciate best practices. It is time to step away from the knowledge-deficit approach of dissemination and move toward learning how to speak to the public (Simis et al. 2016).

We propose that universities hire translational ecologists as faculty and build formal training programs in translational ecology. Translational ecology integrates best practices from sociology, psychology, and communication with ecology to facilitate user-oriented research (Schlesinger 2010). Projects are designed and implemented with two-way communication between intended users and scientists at their core to facilitate improved understanding of key societal concerns and to foster user understanding of the value and rigor of ecological knowledge (Brunson and Baker 2016). Translational ecology is unique because it is a research endeavor itself, combining emphasis on communication with application of the scientific method and rigorous assessment of results to consider social and ecological outcomes.

While institutions increasingly highlight communicating with the public as an ethical obligation of science (Pearson 2001), the academic incentive structure rarely prioritizes or allows sufficient time to do public engagement well. Academics could move toward a model where specific individuals within each department are responsible for studying and conducting translational ecology. Such an addition could cascade out to help other ecologists better communicate their science and facilitate training of ecology graduate students in communication. Translational ecology can serve as an interdisciplinary view of ecology, and translational ecologists should be equivalent with community, ecosystem, and landscape ecologists as a respected sub-discipline.

We must also begin to cultivate communication structures where we can effectively influence public perceptions of science by creating science advocates. As private sectors have lobbyists that advocate for them, science must begin to better voice their value and interests in public spheres. Ecology is well positioned to lead this reform because of the social implications of our research. Citizen science (Bonney et al. 2009), clear reporting on science in traditional media (Sampei and Aoyagi-Usui 2009), effectively incorporating new mass-media opportunities into academic practice (e.g., Instagram, Twitter, Facebook, The Conversation), and facilitating integration of authentic science into the formal classroom (Songer et al. 2003) are all potentially effective pathways to shape public perceptions of science. Investing in communication best practices and developing intimate relationships of trust with the public and government will help secure our role financially and ensure our impact is large in 21st-century social discourse.

Given our socio-political climate, ecology is at a turning point where we must ask "Do we need to rethink our role in society?" If we do, what structural/institutional changes must occur? Are there universities and professional societies ready to lead? Is there a place for advocacy in science? Smith and Gunstone (2009) wrote: "The education that inducts an intending scientist into his or her new community, also acts to remove the child from the responsibilities of an ordinary citizen." The separation between scientist and citizen is not intentional, rather a consequence of the nature–society disconnect that can permeate ecology training. There are clear pathways for the discipline to improve science-communication practices (Table 1) and reconceptualize the role ecology plays in society.

Synthesis

The need for ecology will only grow as we attempt to understand and respond to 21st-century environmental change. Improving careers and culture in ecology should foster advancement in ecological science and help us expand our influence on public discourse and policy. We would like this paper to catalyze action and partnerships among students, professional ecologists, and the ESA to address key barriers in careers, making our community inclusive, and communicating science. Panacea solutions are unlikely, and progress will certainly be incremental. However, much could be accomplished if approached strategically and if outcomes are assessed rigorously. We are responsible for stewarding ecology at the beginning of the ESA's second century. Let us work together to ensure that future is vibrant by addressing these challenges and others facing ecologists.

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